Gabriela VLĂSCEANU[1], Nicole-Livia PETCULESCU[1,2,3]

[1] *Bioterra University, Bucharest*
[2] *Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Sisești", Bucharest*
[3] *Institute of Agricultural Economics, Romanian Academy, Bucharest*
[1] *ga.vlasceanu@yahoo.com;*
[2,3] *nicole.petculescu@asas.ro*

SEA BUCKTHORN – A PRODUCT INTEGRATED IN THE CIRCULAR ECONOMY

ABSTRACT

Sea buckthorn is a shrub able to prevent soil erosion and increase soil fertility, as it assimilates atmospheric nitrogen directly in the roots, and also serves as an economic source of food and medicine. Research conducted has shown that sea buckthorn leaves, fruits, and shoots contain a number of biologically active substances with an essential role in regulating the metabolism. It is very popular for its golden-orange fruits, which provide vitamins and other nutrients (flavonoids and a number of oils rich in essential fatty acids). The present paper shows that the residues from the primary processing of sea buckthorn fruits are still rich in minerals, vitamins, fatty acids and thus become a valuable raw material for further processing into premixes (used for livestock feeding) and for phyto-pharmaceutical products (food supplements). Sea buckthorn is a huge natural resource with extraordinary economic value, useful for business in rural areas and in the production of organic products, environmental protection, and biotechnology.

Key words: sea buckthorn, nutraceutical value, economic value.

JEL Classification: Q13, Q01.

1. INTRODUCTION

Sea buckthorn *(Hippophae rhamnoides*), a member of the *Elaeagnaceae* family, grows naturally in sandy soils at an altitude of 1200–4500 meters (since it originates from Tibet) and withstands cold weather. It can be also grown at lower altitudes in temperate areas.

Sea buckthorn is considered one of the most valuable agronomic and economic species of fruit shrubs in the spontaneous and cultivated flora (Dharmananda S., 2017). It is a true green pharmacy, thanks to the bioactive substances present in the plant. The present study wishes to highlight its pharmaceutical, food, and nutraceutical qualities, the possibility of managing this crop within the concept of sustainable development, applying the circular economy principles, as management

model in rural development by promoting the eco-reconstructive properties of the sea buckthorn.

The case study is located in Bacău county, Vultureni commune. The Eco Catena company was established by a young couple of farmers in 2011, as a farm cultivating fruit shrubs, with a processing facility, resulting from an investment programme with European funding. Sea buckthorn is cultivated on 28 ha, and the fruits are processed in a conditioning and processing facility of about 1500 m². The main products are juices (cold pressed), fruit powder and essential oils used in the pharmaceutical industry. The entire chain (production and processing) is organically certified. The company provides jobs for the local people, both for farming operations and processing. A special feature was the employment of elderly women for certain precision manual operations in conditioning and packaging.

The present paper shows that the by-products (residues) from the primary processing of sea buckthorn fruits are still rich in minerals, vitamins, fatty acids and thus likely to become a valuable raw material for further processing into premixes (used for feeding livestock) and for phyto-pharmaceutical products (food supplements). Thus, the sea buckthorn, by its agro-technical advantages (use of low- quality soils, nitrogen fixation, preventing erosion and no fertilizer use) and by the complete use of fruits, is a perfect example of integration in the circular economy.

2. STATE OF KNOWLEDGE

In the classical Tibetan medicine of the 8th century, in the book *"Djud-shi"* by doctor Yuthog Yontan Gonpo, more than 300 medicinal recipes from sea buckthorn in combination with other plants, minerals, or even food are presented, processed primarily in juice or extracts, and further processed in various forms, such as powders, tablets, patches, compresses, ointments or pastes (Raţi and Raţi, 2003).

Sea buckthorn is a fast-growing, multifunctional leafy plant that serves as a biodiversity conservation measure, in soil conservation, and as a source of medicine, food, fodder and firewood. *"It has an extraordinary ability to grow and survive in adverse conditions (-40 to +40°C) and has an extensive underground root system with strong soil-binding capacity, useful for soil stabilization, river bank control and water retention"* (Li and Schroeder, 1996).

The use of sea buckthorn illustrates how low input costs and a careful planning can lead to substantial benefits, being a good example of sustainable development in a rural area located in a hilly area. "*It qualifies as a unique option for the simultaneous management of several problems emanating from the fragility, marginality, inaccessibility and diversity that characterize mountain areas"* (Lu, 1992, 193, 1996).

In Romania, sea buckthorn grows spontaneously in the Subcarpathian area (in the North-East: Vrancea, Trotuș – Bacău basins) and in the Danube Delta.

3. MATERIAL AND METHOD

In order to specify the conditions for a complete utilization, the analyses were carried out on fruit samples (harvested between August and February).

Both fresh and dried fruits were used as biological material, harvested from local populations in the mentioned areas and analyzed according to the calendar dates presented in the tables. As a technique, specific validated methods were applied:

- *The total content of free amino acids* – separative by partition chromatography;
- *Carotenoids in the oil* – spectrophotometry to maximum absorption bands;
- *Macro elements* – by activation with thermal neutrons;
- *Microelements* – by atomic absorption spectrophotometry;
- *Oil extraction* – using acetone and the Soxhlet method;
- *Moisture determination* – gravimetrically;
- *The concentration in* water-soluble substances – refractometrically;
- *Total acidity* – by the classic acidimetric method;
- *Vitamin C content* – with 2,4-dichlorophenol-indophenol;
- *Nicotinic acid* – by the LCMSMS method;
- *Vitamin B* – dosed fluorometrically.

The product quality check is carried out in accordance with the European Pharmacopoeia for *heavy metals* (through atomic absorption spectrometry) and in accordance with the Romanian Pharmacopoeia, chapter IX. D.1. for *macroscopic characters* (identification A from FR X), *loss on drying* (dry in an oven at 105 °C ± 2 °C for 2 hours – the result is expressed in %), *total ash* (FR X – chapter 2.4. 16), *dosing fatty oil content* (Soxhlet method).

Sea buckthorn *(Hippophae rhamnoides)* in the form of fruit powder, used as a raw material, must meet certain technical specifications (Table 1).

Table 1

Characteristics and admissibility limits for the raw material

Characteristics	Admissibility limits
Description: – aspect – color – smell	Semi-fine homogeneous yellow-brown-reddish powder
Size	Semi-fine powder (sieve no. 355/sieve no. 180)
Identification: – carotenoids (UV-VIS spectrophotometry)	positive
Loss on drying, %, max.	12.0
Total ash, %, max.	1.5
Ash insoluble in hydrochloric acid, %, max.	0.5
Heavy metals – lead (Pb), ppm, max. – cadmium (Cd), ppm, max.	 5.0 1.0

Table 1 (continued)

Included in: – lipids, %, max. – total polyphenols expressed in chlorogenic acid % min	 10.0 1.0
Total number of viable aerobic microorganisms: – bacteria, UFC/g, max. – yeasts and filamentous fungi, UFC/g, max – gram-negative bacteria tolerant to bile salts, CFU/g – *Escherichia coli*, UFC/g – *Salmonella sp*., UFC/25 g	 10^5 10^4 10^4 Absent Absent

Source: European & Romanian Pharmacopoeia; Hofigal technical specifications

All analyses shown in the present paper were performed in three different laboratories, certified for organic products.

4. RESULTS AND DISCUSSIONS

Generally, the content of various physiologically active substances in sea buckthorn fruits varies depending on *pedoclimatic factors, the time of harvesting and biotype*. Following the field trips, it was found that, if the ground is not covered with snow, the fruits persist on the shrubs until the end of February.

The determinations regarding the variation of total acidity expressed in malic acid do not show very large differences between areas and harvest dates (the variation between the content of various organic acids from sea buckthorn metabolism, which were not analyzed separately, is not excluded) (Table 2, Table 3, Figure 1).

Table 2

Variation of acidity in non-defatted and defatted dry sea buckthorn fruits, harvested from different areas and on different data

Harvest date	Variety	Malic acid (g%)	
		Non-defatted	Defatted
14.09.2021	Vrancea yellow berries	11.56	15.15
	Vrancea orange berries	11.32	12.98
	Vrancea medium grains	10.49	11.73
	Vrancea large grains	15.32	–
21.09.2021	Trotuș yellow berries	8.14	–
	Trotuș orange berries	8.38	13.80
	Trotuș medium grains	8.00	14.66
27.09.2021	Vrancea	9.87	–
	Trotuș	9.07	–
January 2022	Vrancea	8.13	–
	Trotuș	7.99	–
July 2022	Trotuș	6.30	9.60
	Vrancea	6.50	9.00

Table 2 (continued)

August 2022	Vrancea	9.36	11.70
	Trotuș	9.52	12.9
September 2022	Trotuș	10.90	–
	Vrancea	7.68	–

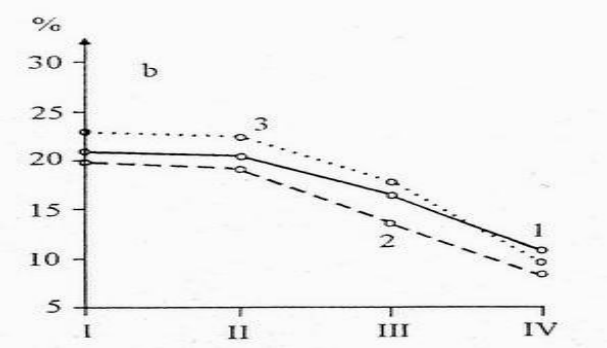
Source: Analyses performed by authors

Table 3

Fatty acid composition of sea buckthorn oil harvested from the Vrancea area, g%

Myristic acid	0.41
Palmitic acid	34.17
Palmitoleic acid	25.68
Stearic acid	0.89
Oleic acid	31.46
Linoleic acid	5.44
Linolenic acid	1.94

Source: Analyses performed by authors

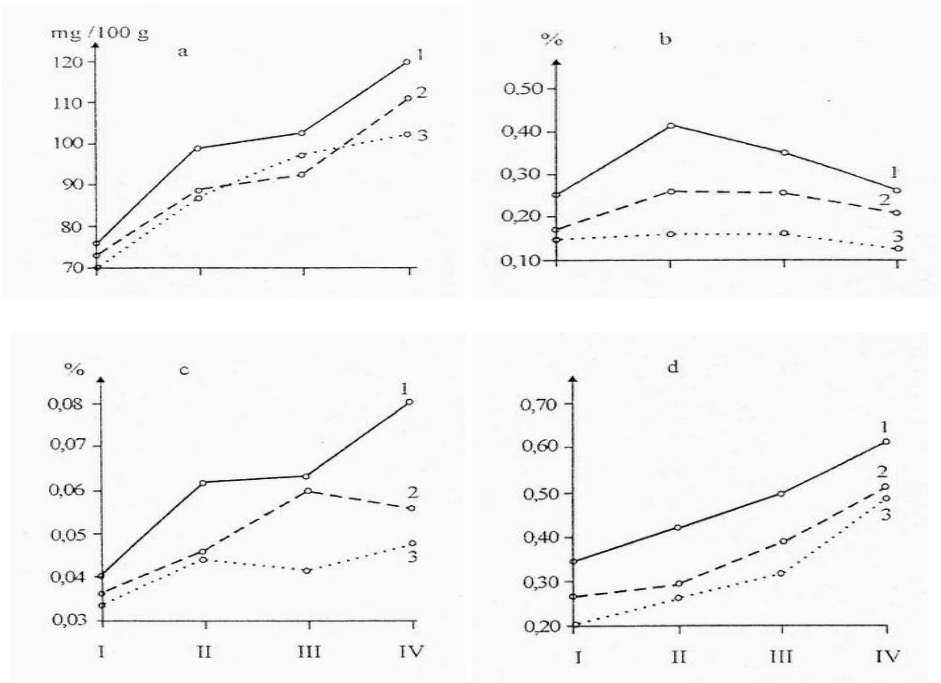


Source: Analyses performed by authors

Figure 1. The variation in the content of fatty acids in sea buckthorn fruits:
in the Vrancea mountain area; 2 – in the Trotuș hilly area; 3 – in the low area

The analysis of the variation of ascorbic acid in dry sea buckthorn fruits shows an increase in the values as the vegetation progresses from semi-maturity (August) until the threshold of winter, after which it fluctuates during the post-ripening of the fruits on the shrub (Table 4).

It can be noticed that the fruits from the sea buckthorn in the low areas have a lower ascorbic acid content in all investigated vegetation phases than the similar samples collected from the biotypes at higher altitudes.



Source: Analyses performed by authors

Figure 2. Variation of nicotinic acid (a), vitamin B1 (b), caffeoylquinic derivatives (c), carotenoids (d) from sea buckthorn fruits; in the mountainous area of Vrancea; 2 – in the Trotus hilly area; 3 – in the low area

Table 4

The variation of ascorbic acid content (mg/%g) in defatted and dried fruits, harvested from different areas and on different dates

Biotopes, year and harvest time	Vrancea	Trotus
1 – August	162.25	151.32
2 – September	235.13	174.95
3 – November	205.06	225.12
4 – February	205.06	195.34
1 – August	104.23	95.70
2 – September	164.16	156.34
3 – October	173.82	181.22

Source: Analyses performed by authors

The content of total carotenoids in oil, regardless of the harvest area, increases from summer to winter, by approximately 50%. However, in the same period, a decrease in oil content is noticed. Increasing the content of carotenoids is achieved by increasing the content of carotenoids that are not provitamin A (Table 5).

Table 5

Variation of total carotenoid content (mg/100 oil),
in fruits harvested from different areas and on different data

Biotopes, year and harvest time	Vrancea	Trotuș
1 – August	92.35	89.16
2 – September	99.15	95.42
3 – October	103.03	91.13
4 – November	105.12	95.30
5 – December	131.48	125.50
6 – January	95.46	83.75
7 – February	61.05	57.25

Source: Analyses performed by authors

The high protein content can be noticed, at the same time with a small variation in relation to the variation of the amino acid content in the juice; this is due to the fact that the largest amount of protein is found in seeds. At the same time, we note that the iodine index is relatively low (it is surprising, however, that the oil is liquid at room temperature, which does not usually happen with oils with a low iodine index). But if it is exposed to lower temperatures, the oil becomes semi-solid (by lowering the temperature, some fat-soluble substances solidify) (Table 6).

The determination of the content of macro- and micro-elements at intervals of 2 months proves that the content of these substances also depends on the time of harvesting (Table 7).

Table 6

Variation of total nitrogen content (crude protein) and oil quality in sea buckthorn fruits, harvested from different areas and on different data

Harvest time	Area	Defatted fruits	Oil	
		Brute protein (g%)	Refraction index	Iodine index
14.09.2021	Vrancea	17.33	1.4682	67.19
21.09.2021	Trotuș	16.93	1.4645	68.89
January 2022	Trotuș	16.47	1.4678	67.80
January 2022	Vrancea	18.33	1.4683	66.10
February 2022	Trotuș	18.98	1.4683	68.10
May 2022	Vrancea	17.87	1.4680	66.50
June 2022	Trotuș	19.67	1.4670	73.50
July 2022	Vrancea	17.87	1 .4676	69.30
August 2022	Trotuș	17.92	1.4685	81.70
September 2022	Vrancea	18.87	1.4670	79.50

Source: Analyses performed by authors

Table 7

The content of sea buckthorn fruits in macro- and micro-elements, harvested on different data

Element	1st harvest (October) Mediate ± s	2nd harvest (December) Mediate ± s
Ca%	19.832 ±1.188	8.013 ±0.561
K%	8.45 ± 0.42	22.06+1.10
Na%	4.095 ± 0.082	2.11 7 ±0.042
Fe%	1.261 ±9.063	0.635 + 0.032
Zn ppm	401 ±28	895 + 36
Ba ppm	421 ± 70	156 + 37
Rb ppm	105+11	213+24
Br ppm	127+2	66 ±2
Cr ppm	36 ±3	18±2
Ce ppm	20 ±2	11+2
As ppm	15 ±1	4.8+0.5
La ppm	12 ±1	5.1 ±0.2
Co ppm	6.4 ±0.6	3.9 ±0.4
Th ppm	2.8 ± 0.3	1.2 + 0.2
Se ppm	2.8 + 0.1	1.5+0.1
Cs ppm	2.3 ± 0.6	1.3 ±0.3
Sm ppm	1.83+0.07	0.9 + 0.05
Yb ppm	1.4 ±0.4	0.9 ± 0.3
Hf ppm	1.5+0.3	0.5+0.2
Sb ppm	1.3+0.1	0.9 ±0.1
Au ppm	260 ±10	94 + 6

Source: Analyses performed by authors

The phenomenon is explained by the migration of these elements from root to stems and leaves in autumn and winter, as a consequence of the adaptation of the plant metabolism to winter conditions.

The results show that in all samples the chemical and microbiological content is within the established limits, its quality allowing the use of residues for processing into further products, intended for human or animal consumption. Thus, the fruits are completely used, with no by-products after the secondary processing.

5. CONCLUSIONS

Sea buckthorn fruits are valued as natural multivitamins because they are rich in the main vitamins (A, B_1, B_6, C, E, F, K, and P). Vitamin C content of sea buckthorn exceeds not only all native fruit species, for example, black currant, but even citrus (lemon) by more than 10 times. The leaves additionally contain triterpenes and are used to make tea. So, sea buckthorn *(Hippophae rhamnoides)*, with a complex chemical composition is useful in the prophylactic and curative

treatment of serious current diseases, such as cardiovascular, liver, gastrointestinal, skin, geriatric, nervous, and oncological conditions as shown in literature.

Sea buckthorn is also an agro-phyto-technical plant, being planted to prevent erosion and increase soil fertility, because it assimilates atmospheric nitrogen directly in the roots; it does not require fertilization, it has a high dredging capacity, with the effect of fixing and consolidating highly degraded lands (the phenomenon of restoring the ecosystem being quite fast); ensures erosion control and slope stability through deep roots (up to 6 meters deep), thus contributing to ecosystems restoration.

From the economic point of view, 100% of fruit and by-products resulting from pressing is used. They are collected at the end of the production process, because they still contain a large amount of antioxidant compounds, which can be further used in other production processes such as: obtaining premixes for animal feed, and bio-compost, thus being able to be included in another category of value, that of the by-product, applying the principles of circular economy.

Sea buckthorn is a valuable natural resource that can favor the development of the business environment in rural areas and the creation of ecological products. It can become an important source of income, being able to attract investment, but it can also be a valuable element for environmental protection, biotechnology, and business development.

REFERENCES

1. Brad I., Brad I.L., Radu F., (2002), *Sea buckthorn, a pharmacy in a plant* – Edit. Technica, Bucharest.
2. Chen Y. *et al*., (2003), *Study on the effects of Hippophae rhamnoides oil in hematopoiesis,* Chinese herbal medicine; 26 (8); 572–575.
3. Dharmananda S., (2017), *Seabuckthorn*, Institute of Traditional Medicine (ITM), Portland, USA, http://www.itmonline.org/arts/seabuckthorn.htm.
4. Hofigal – *Technical specifications*, https://hofigal.eu/, accessed 25.09.2021.
5. Ianev E. *et al*., (1995), *The effect of a sea buckthorn extract on the healing of experimental skin wounds in rats*, Dermatology; 48(3): 30–33.
6. Li T.S.C., Schroeder, W.R. (1996), *Sea buckthorn (Hippophae rhamnoides L.): A multipurpose plant.* HortTechnology 6:370–380.
7. Lu R. (1992), *Seabuckthorn – A multipurpose plant species for fragile mountains*, ICIMOD Paper no. 20. Kathmandu, Nepal. 62 p.
8. Lu R. (1993), *The chemical composition of Hippophae fruits in China*. In: Proceedings of International Symposium on sea buckthorn (H. rhamnoides L.). 1993, Barnaul, Russia. pp. 398–412.
9. Lu R. (1999), *A new sea buckthorn resource – H. goniocarp*, Proceedings of International Symposium on Sea Buckthorn (H. ramnoides L.), Beijing 1999, China.
10. Raţi I.V., Raţi L., (2003), *Sea buckthorn in agricultural holdings*, https://fdocumente.com/document/catina-in-exploatatii-agricole-56548c5e2d837.html, accessed 25.11.2021.
11. Xing J. *et al*., (2002), *Effect of sea buckthorn seed and pulp oils on experimental models of gastric ulcer in rats*, Fitoterapia; 73 (7–8): 644–650.
12. Yang Baoru *et al*., (1998), *Effect of dietary supplementation with sea buckthorn oils on fatty acids in patients with atopic dermatitis*, 1999 Proceedings of the International Sea Buckthorn Congress, ICRTS, Beijing.

13. Zhou Yuanpeng *et al*., (1998), *Study on the effect of sea buckthorn seed and pulp oils against gastric ulcer*, Institute of Medicinal Plant Resources Development, Chinese Academy of Medical Sciences, Beijing.
14. *** European Pharmacopoeia, accessed 10.09.2021
15. *** Romanian Pharmacopoeia, chapter IX. D.1. accessed 10.09.2021
16. *** LS – "Village world", published in "Agrotehnica", accessed 20.09.2022 https://www.lumeasatului.ro/
17. ***ZF – "Financial Journal", accessed 27.09.2022.
18. https://www.zf.ro/afaceri-de-la-zero/