



Article

A Study on the Fruiting and Correlation between the Chemical Indicators and Antimicrobial Properties of *Hippophae rhamnoides* L.

Natalia Netreba ^{1,*} , Elisaveta Sandulachi ¹, Artur Macari ¹, Sergiu Popa ^{2,*} , Ion Ribintev ² , Iuliana Sandu ¹, Olga Boestean ¹ and Irina Dianu ¹

¹ Faculty of Food Technology, Technical University of Moldova, 168 Ștefan cel Mare Street, MD-2004 Chișinău, Moldova; luiza.sandulachi@gmail.com (E.S.); artur.macari@tpa.utm.md (A.M.); iuliana.sandu@tpa.utm.md (I.S.); olga.boestean@tpa.utm.md (O.B.); irina.dianu@doctorat.utm.md (I.D.)

² Faculty of Agricultural, Forest and Environmental Sciences, Technical University of Moldova, 168 Ștefan cel Mare Street, MD-2004 Chișinău, Moldova; ion.ribintev@h.utm.md

* Correspondence: natalia.netreba@tpa.utm.md (N.N.); sergiu.popa@h.utm.md (S.P.)

Abstract: Sea buckthorn is a promising species that, under the conditions of Eastern Europe, has shown high productivity and is also a good and possible source of a wide range of bioactive compounds that have a positive effect on the human body, especially polyphenols and carotenoids. Due to the content of biologically active substances in sea buckthorn (*Hippophae rhamnoides* L.), the species is of growing interest to scientists, the food industry, the pharmaceutical industry, the cosmetics industry and consumers. The aim of this study is to investigate the productivity and the correlation between the chemical composition and the antibacterial effect of four cultivars of sea buckthorn (Clara, Dora, Cora, Mara), cultivated in the Republic of Moldova. Sea buckthorn fruits were harvested at the stage of full ripening. Berry samples were frozen at minus 25 °C, stored for 6 months and whole fruits of sea buckthorn were studied. All quantitative characteristics were calculated in terms of absolutely dry raw material (dry weight). The sea buckthorn cultivars tested were found to have a different carotenoid contents (1.79–48.92 mg/100 g), ascorbic acid contents (74.36–373.38 mg/100 g), organic acids (malic acid 5.8–13.4 mg/100 g, citric acid 0.08–0.321 mg/100 g, succinic acid 0.03–1.1 mg/100 g), total dry matter contents (16.71–24.54%), titratable acidities (2.15–8.76%) and pH values (2.73–3.00). The antimicrobial activity of sea buckthorn, evaluated by the diameter of the inhibition zone, constituted for *Bacillus pumilus* 3.70–15.91 mm/g^{−1} for whole sea buckthorn fruits and 13.33–26.67 mm/g^{−1} for sea buckthorn purees.

Keywords: sea buckthorn; variety; productivity; *Hippophae rhamnoides* L.; carotenoids; antimicrobial activity; *Bacillus pumilus*



Citation: Netreba, N.; Sandulachi, E.; Macari, A.; Popa, S.; Ribintev, I.; Sandu, I.; Boestean, O.; Dianu, I. A Study on the Fruiting and Correlation between the Chemical Indicators and Antimicrobial Properties of *Hippophae rhamnoides* L. *Horticulturae* **2024**, *10*, 137. <https://doi.org/10.3390/horticulturae10020137>

Academic Editors: Lixiang Miao and Xiaobai Li

Received: 15 December 2023

Revised: 22 January 2024

Accepted: 23 January 2024

Published: 31 January 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Due to its valuable nutritional benefits and therapeutic properties, sea buckthorn has gained a particular attention and interest compared with other species of flowering plants. Despite this, sea buckthorn has not known a widespread cultivation due to the low productivity of the plants and the presence of dense thorns, which represents a major impediment to manual harvesting. However, with the emergence of highly productive varieties (20 t/ha) and fruit harvesting machines, producers are showing an exceptional interest in sea buckthorn cultivation and the crop is in high demand (in unlimited quantities) on the international market.

Sea buckthorn is a relevant source of vitamins (the most important being vitamins C and E, but vitamins B₁, B₂ and K and bioflavonoids are also present), macro and microelements (nitrogen, phosphorus, iron, manganese, boron, calcium, aluminium, silicon and others) and antioxidants (catechin, myricetin, quercetin, p-coumaric acid, caffeic acid, L-ascorbic acid and gallic acid) [1–4]. Currently, papers containing experimental data

obtained by various international researchers supporting the consumption of sea buckthorn fruits as functional foods [5–7], the use of the fruit as therapeutic remedies [8–10] and their use as sources of natural antioxidants with antimicrobial properties by the food industry [11–14]. Sea buckthorn fruits have a great potential as antimicrobial compounds against microorganisms [15,16]. So, these berries can be used to control the stability of stored food [17,18].

The antioxidant and antimicrobial activity of sea buckthorn depends on the chemical composition of the berries [19,20]. Published experimental data [21,22] support the consumption of sea buckthorn fruits as functional foods and their use as sources of natural antioxidants by the food industry. The content of biologically active substances and the level of antioxidant activity of sea buckthorn depend on growing conditions, agricultural technology and climate [23,24].

The aim of this study was to determine the relationship between the antimicrobial properties of sea buckthorn fruits and the chemical parameters (ascorbic acid content (AAC), organic acids (OA), carotenoid content (CC), total dry matter (TDM), titratable acidity (TA) and pH) of the berries.

2. Materials and Methods

2.1. Biological Materials

The experimental plantation was established in the spring of 2015 in the Dubasari district, located in the central fruit-growing area of the Republic of Moldova (47°10'34" N 29°10'04" E). The soil in this region is a light-textured carbonate chernozem. The sea buckthorn plants of Mara, Cora, Clara and Dora cultivars, selected at the Centre of Excellence and Production of White Hawthorn in Arad, Romania, were used as the objects of the study. They were planted at 3.5 × 1.75 m spacing. The Andros variety was used as the pollinator and was planted according to the formula of 8 female plants and 1 male plant. The trees were formed according to the crown shape—free growing bush. The soil in the experimental plantation is maintained as a natural tillage between the rows, which is mowed when the height is more than 20 cm, and on the row of trees the soil is loosened with a tiller when weeds appear. The plants are drip irrigated and the volume of water is determined by the moisture content of the soil, which should be 75–80% of the field capacity. As the fruit production is organic, no fertilisation and treatments against plant pathogens are carried out in the experimental plantation.

Sea buckthorn fruits were harvested at the stage of full ripening. Berry samples were frozen at minus 25 °C. In this work, frozen sea buckthorn fruits stored for 6 months under these conditions were studied.

The cultivars studied are of Romanian origin and have been approved and included in the Catalogue of Plant Varieties for the Republic of Moldova [25].

Figure 1 show the sea buckthorn varieties analysed.

Characteristics of the Cultivars Studied

Clara—The tree is of high vigour, has a thick and compact crown, medium capacity to form 4–6 cm thorns, high regeneration capacity, fruits in the third year after planting, fruits on annual and early branches, high productivity and is resistant to fusariosis and overwintering. Fruits are medium sized, elongated and orange-yellow with thin skin. The mass of 100 fruits is 38–42 g; they are 11–12 mm long and 7–8 mm in diameter. The peduncle length is 3–4 mm. In the conditions of the Republic of Moldova, the fruits ripen at the end of July–mid-August and they have a universal destination.

Mara—The tree is of high vigour, has a rare crown with a high capacity for regeneration and forms thorns 3–5 cm long. It comes into fruit in the third year after planting, fruits regularly on annual and early branches, has high productivity and is immune to fusariosis. Fruits are medium sized, with a mass of about 0.3 g each, are dark orange-orange in colour and have elastic and tough skin. The fruit is 9–10 mm long and 6–7 mm in diameter. The

length of the stalk is 3–5 mm. The flesh is juicy with a sweet–sour taste. The ripening of the fruit under Moldovan conditions takes place in mid-August.

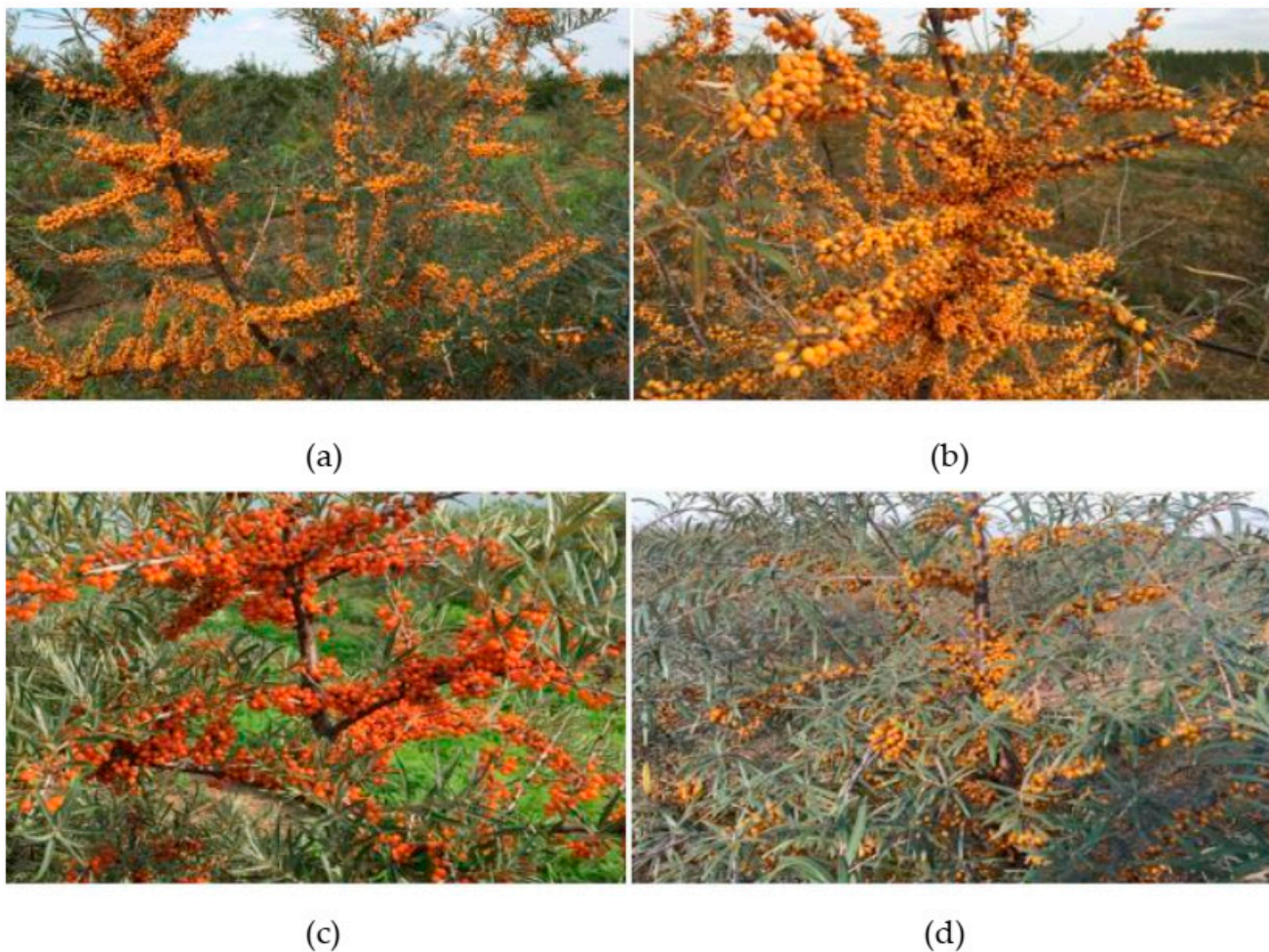


Figure 1. Sea buckthorn cultivars grown in the Republic of Moldova: (a) Clara; (b) Mara; (c) Dora; (d) Cora.

Dora—The tree is of medium to weak vigour, with a thick crown, high capacity to form thin thorns and, although 3–5 cm long, comes into fruit in the third year after planting. It fruits regularly on annual and early branches and has low productivity. Fruits are medium sized, with a mass of about 0.45 g each; they are elliptical in shape, dark orange to red in colour and sour-tasting, with a strong pineapple and melon flavour. The fruit is 8–9 mm long and 6–7 mm in diameter. The stalk is 1–2 mm long. The ripening of the fruit under Moldovan conditions takes place in late July–early August; the fruits are valuable for combining with other juices.

Cora—The tree is of high vigour, exhibits erect growing and is thick and resistant to diseases and pests; it has a high capacity to form sparse thorns 3–5 cm long on branches, comes into fruit in the third year after planting, fructifies on annual and early branches and has high productivity. Fruits are small, 9–10 mm long and 6–7 mm in diameter, oval, yellow-orange in colour, with elastic and resistant skin. The fruit stalk is 3–5 mm long. The fruit ripens in the Republic of Moldova in late August–early September [25].

2.2. Chemical Materials

The methanol (>99.9%) and ethyl acetate, ($\geq 99.9\%$) were provided by Honeywell (Charlotte, NC, USA); petroleum ether puriss. p.a., ACS reagent, reag. ISO, low-boiling-point hydrogen-treated naphtha, $b_p > 90\%$ 40–60 °C ($\geq 90\%$), hydrochloric acid solution,

sodium 2,6-dichloroindophenolate hydrate ACS reagent, sodium hydroxide for the preparation of dilute volumetric solutions or for direct use, phenolphthalein indicator ACS, Reag. Ph Eur, hydrochloric acid for the preparation of dilute volumetric solutions or for direct use, benzoic acid (ACS reagent, $\geq 99.5\%$), cetrimonium bromide (grade pharmaceutical primary standard) and diethalonamine reagent ($\geq 98.0\%$) were provided by Sigma-Aldrich (Schnelldorf, Germany); a MPW-380R centrifuge was purchased from IKA®-Werke GmbH & Co (Baden-Württemberg, Germany/Deutschland); a Shimadzu UV-1900 UV-VIS spectrophotometer was obtained from Shimadzu Europa GmbH (Duisburg, Germany); and a capillary electrophoresis system KAPEL-105M was purchased from LUMEX, Saint-Petersburg, Russia.

2.3. Physicochemical Analysis

The total dry matter (TDM) was determined according to a gravimetric method based on the weight loss of the analysed sample to a constant mass due to water evaporation by heating in an oven at a temperature of up to $105 \pm 2^\circ\text{C}$ and at atmospheric pressure [26]. The titratable acidity (TA) was determined according to potentiometric titration, with a standard volumetric solution of sodium hydroxide in the presence of phenolphthalein as an indicator [26]. The pH was measured with a Titrator SI Analytics TitroLine® 5000 (Xylem Analytics, Letchworth, UK) at 20°C .

2.4. Content of Biologically Active Substances

Frozen sea buckthorn fruits were thawed at a constant temperature of $4 \pm 2^\circ\text{C}$ and a relative humidity of 75–80%. Thawing was carried out for 2 h. Thawed sea buckthorn fruits were crushed and extracts were prepared. All quantitative characteristics were calculated in terms of absolutely dry raw material (dry weight (DW)).

The ascorbic acid content (AAC) was determined via potentiometric titration [27].

The method is based on vitamin C extraction with hydrochloric acid solution followed by titration with 2,6-dichlorophenolindophenolate sodium.

A solution of hydrochloric acid with a mass fraction of 2% was used as an extraction solution. The solution for titration of 0.05 g of 2,6-dichlorophenolindophenolate was dissolved in pre-boiled water (150 mL) for 30 min, cooled and the solution was made up to 200 mL. The shelf life of the solution was not more than 10 days. The titre of the 2,6-dichlorophenolindophenolate sodium solution was established using a standard ascorbic acid solution with concentrations of 1.0 and 0.1 g/dm³ on the day of the test.

Extraction—A 5 g sample weight was weighed with an accuracy of ± 0.01 g, homogenised for not more than 2 min with a small amount of extraction solution and transferred into a 100 cm³ volumetric flask, washing the homogeniser with a small amount of extraction solution until the volume reached the mark. The contents were incubated for 10 min, then stirred and filtered. Pipette 0.5 to 1.0 mL of extract into a 50 cm³ beaker, add extraction solution to a volume of 30 cm³ and immerse pH electrodes of the millivolt meter so that when stirring they do not touch the magnetic stir bar. Then, they are titrated potentiometrically from a microburette with sodium 2,6-dichlorophenolindophenolate solution. Sodium 2,6-dichlorophenolindophenolate solution is added in portions of 0.1–0.2 cm³ with constant stirring. The volume of sodium 2,6-dichlorophenolindophenolate solution corresponding to the equivalence point and, therefore, consumed for the titration volume is determined by the maximum difference (“jump”) of two neighbouring readings.

Organic acids (OA) were determined via the method of capillary electrophoresis using the KAPEL105M system (the most modern of the certified models in the Kapel series). Along with the latest electronic database, the KAPEL105M system implements complete instrument control, data collection and processing using its software and has the ability to record the absorption spectra of the components of the analysed sample during analysis [28–30].

We used an unmodified quartz capillary with an inner diameter of 50 µm and a total length of 64.5 cm (an effective length of 56 cm). The capillary was thermostatically

controlled at 20 °C. Conditions of the research: phosphate buffer was used as the main electrolyte in the work, capillary $L_{\text{eff}}/L_{\text{tot}} = 40/50$ cm, ID = 50 μm . The sample inlet was hydrodynamic at 300 mbar*s, voltage 17 kV. Indirect detection: an UV detector was used at a wavelength of 190 nm (± 1.0 nm). Reagents of ACS grade ($\geq 95\%$) were used for the analysis. Before working, the capillary was successively washed with 0.1 M NaOH solution for 60 s, then twice for 1 min with deionised water and for 5 min with background electrolyte solution between analyses.

The carotenoid content (CC) was determined following the modified method described by Ghendov-Mosanu et al. [31]. The plant material (2 g) was extracted with 25 mL of a mixture of methanol/ethyl acetate/petroleum ether (1:1:1, $v/v/v$). After filtering the extract, the residue was reextracted twice using the same solvent mixture. The TCC was determined using the spectrophotometric method. The absorption spectrum was plotted and the TCC was measured at the maximum absorbance wavelength (450 nm) [26,31,32].

2.5. Antimicrobial Activity

The antimicrobial activity (AA) of sea buckthorn was evaluated via the agar diffusion method. In this study, we used the inhibition zone test, also called the Kirby–Bauer test [33], against the reference bacterial strain *Bacillus pumilus* ATCC 7061—a Gram-positive aerobic spore-forming bacteria cultivated in the microbiology laboratory of the Department of Food Technology, Technical University of Moldova.

Wells with a diameter of 4 ± 0.1 mm were made on Mueller–Hinton agar plates using a sterile metallic cylinder and the distances between neighbouring wells and to the edge of the plate were equal. The previously prepared inoculum was spread uniformly on the surface of the agar plates using a sterile swab. In each well, fruits of sea buckthorn of equal weight were weighed to the nearest 0.01 g or 100 μL of a dissolved puree of sea buckthorn (125 mg/mL dimethyl sulfoxide (DMSO)) was introduced. The plates were kept at +4 °C for 2 h to ensure the diffusion of the extracts in the agar [34] and subsequently incubated at 37 °C for 24 h. The measurement of the total zone of inhibition (including the diameter of the wells) after the incubation period allowed for the detection of antimicrobial activity. DMSO was used as a negative control. All tests were performed in triplicate.

2.6. Statistical Analysis

Data were processed using the STATGRAPHICS Centurion 19.4.04 (Statgraphics Technologies, Inc., The Plains, VA, USA) program. The cultivar means were tested with analysis of variance (ANOVA). The variables showing significant differences between treatments were then evaluated by using Fisher's least significant difference (LSD) test at 5% [35].

The differences were considered statistically significant if the probability was greater than 95% ($p\text{-value} < 0.05$). All assays were performed in triplicate. The experimental results are expressed as average $\pm$ SD [36].

3. Results

3.1. Productivity of Sea Buckthorn Varieties Analysis

The fruit harvest is one of the main indicators to appreciate the influence of the factors under study and is influenced both by internal factors, such as the varieties, and by external factors, such as the climatic conditions and cultivation technologies.

The cross-sectional area of the trunk, which determines the growth vigour of the trees, was influenced by the biological peculiarities of the variety (Table 1). The highest values in the conditions of 2022 were recorded for trees of the Cora cultivar, where the value of the respective indicator was 30.18 cm^2 ; the lowest value was 14.51 cm^2 and was obtained for trees of the Dora cultivar.

Table 1. The main elements of productivity of sea buckthorn cultivars, 2022.

Sea Buckthorn Cultivars	Cross-Sectional Area of the Trunk (CSAT), cm ²	Productivity (kg/Plant)	Fruit Production Relative to CSAT, kg/cm ²	Productivity (t/ha)
Clara	25.3 ± 4.7 a	10.8 ± 2.0 a	0.44 ± 0.15 a	17.8 ± 3.3 a
Cora	30.1 ± 5.6 b	10.7 ± 2.0 a	0.385 ± 0.062 b	17.6 ± 3.3 a
Dora	14.5 ± 2.7 c	2.51 ± 0.47 b	0.20 ± 0.023 c	4.1 ± 0.76 b
Mara	25.5 ± 4.7 a	9.4 ± 1.7 c	0.423 ± 0.063 b	15.4 ± 2.8 c
LSD	3.496	1.292	0.0394	2.109

The means followed by the same letters in the same column are not significantly different according to the LSD test at 5%.

The fruit production obtained per tree and per surface unit in the ecological and technological conditions of 2022 in the Clara and Cora cultivars showed superior values compared with the Dora cultivar. Thus, in the plantation with trees of the Clara cultivar, a production of 17.8 t/ha was obtained, and in the plantation of trees of the Dora cultivar, it was 4.1 t/ha.

Fruit production correlated with the cross-sectional area of the trunk, and this is the indicator that determines the fruiting potential of the variety. Respectively, the highest productivity potential was recorded in trees of the Clara cultivar, where 0.43 kg of fruit was obtained per 1 cm² of cross section in the trunk. Of the studied varieties, the lowest productivity potential was obtained in trees of the Dora cultivar, where the value of the indicator was only 0.17 kg/cm².

3.2. Physicochemical Analysis

Table 2 shows the average values and limits of the physical indicators TDM, TA and pH for the investigated sea buckthorn cultivars Clara, Dora, Cora and Mara.

Table 2. Average levels and range of limits for physical indicators in tested sea buckthorn fruits.

Sea Buckthorn Cultivars	Indicator Tested		
	Total Dry Matter (TDM), %	Titrateable Acidity (TA), %	pH
Clara	17.3 ± 1.3 a	3.25 ± 0.87 a	2.882 ± 0.070 a
Dora	16.7 ± 1.9 a	3.2 ± 1.6 a	2.928 ± 0.034 a
Cora	19.1 ± 2.3 a	4.9 ± 1.6 b	2.760 ± 0.059 b
Mara	18.7 ± 2.3 a	5.9 ± 1.0 b	2.734 ± 0.084 b
LSD	2.404	1.473	0.0775

The means followed by the same letters in the same column are not significantly different according to the LSD test at 5%.

3.3. Content of Biologically Active Substances

Table 3 shows the average values and limits of the CC, AA and OA for the investigated sea buckthorn cultivars Clara, Dora, Cora and Mara.

Table 3. Average levels and range (mg/100 g) for carotenoids, ascorbic acid and organic acids in the tested sea buckthorn fruits.

Sea Buckthorn Cultivars	Chemical Indicators, mg/100 gDW (Number of Samples, n = 42)				
	Ascorbic Acid Content (AAC)	Malic	Organic Acids (OA) Citric	Succinic	Carotenoid Content (CC)
Clara	151 ± 32 a	11.90 ± 0.23 a	0.202 ± 0.023 a	1.101 ± 0.043 a	7.65 ± 0.81 a
Dora	254 ± 43 b	5.80 ± 0.34 b	0.081 ± 0.013 b	0.360 ± 0.041 b	39.8 ± 5.1 b
Cora	113 ± 57 a	9.60 ± 0.11 c	0.090 ± 0.016 b	0.720 ± 0.056 c	4.1 ± 1.1 c
Mara	279 ± 41 b	13.40 ± 0.81 d	0.320 ± 0.002 c	0.031 ± 0.017 a	14.1 ± 3.4 d
LSD	53.22	0.2041	0.011	0.034	3.744

The means followed by the same letters in the same column are not significantly different according to the LSD test at 5%.

As for organic acids, the precision of the evaluation is defined by the parameters used in the analysis device features.

3.4. Antimicrobial Activity Analysis

Table 4 shows the interdependence between the AA of sea buckthorn fruits and purees and the contents of TDM, CC, AAC, TA and pH through the Pearson correlation coefficient.

Table 4. Pearson correlation coefficient values between the chemical indicators and antimicrobial properties of sea buckthorn.

Sea Buckthorn Cultivars	Mass, g	Pearson Coefficient				
		Pc = f(AABacillus pumilus and PCI)				
		TDM	CC	AAC	TA	pH
Whole Sea Buckthorn Fruits						
Clara	0.28–0.30					
	0.10 *	0.8520	0.8488	0.5738	0.9762	−0.9524
	0.25 *	0.8525	0.8473	0.5727	0.9766	−0.9534
Dora	0.16–0.19					
	0.10 *	0.9791	0.9791	0.9791	1.0000	−0.9628
	0.25 *	0.9758	0.9758	0.9758	1.0000	−0.9758
Cora	0.16–0.19					
	0.10 *	0.7154	0.7179	0.9689	0.9689	−0.9952
	0.25 *	0.8417	0.8443	0.9766	0.9927	−0.8429
Mara	0.16–0.20					
	0.10 *	0.9261	0.9209	0.8714	0.9706	−0.9280
	0.25 *	0.9254	0.9202	0.8704	0.9704	−0.9273
Sea Buckthorn Purees						
Clara		0.8232	0.8526	0.5174	0.9883	−0.9588
Dora		0.9577	0.9577	0.9577	1.000	−0.9582
Cora	-	0.7174	0.7552	0.7178	0.7061	−0.7720
Mara		0.9035	0.9940	0.9035	0.7780	−0.9047

* Recalculated.

The AA (inhibition zone diameter in mm) of the samples was also evaluated against *Bacillus pumilus*.

Table 5 presents two specific models for whole sea buckthorn fruit (hyperbolic model) and sea buckthorn puree (linear model). The parameters of the regression model were estimated in the Standgraphic Soft programme and the accuracy was estimated using Student's 95% variant for whole sea buckthorn fruits and sea buckthorn purees.

Table 5. Comparative analysis of the antibacterial activity (AA) (diameter of inhibition zone in mm) by using biometrical models.

Whole Sea Buckthorn Fruits			
	Intercept	Slope	
Clara	0.093144	−0.01583	
Dora	0.096479	−0.21127	
Cora	0.097657	0.039655	
Mara	0.159398	−0.1807	
Sea Buckthorn Purees			
	Constant	Time	×1
Clara	18.2303	−1.44478	38.7097
Dora	18.5423	−1.15536	19.8787
Cora	17.601	−0.49881	53.2813
Mara	19.7681	−1.79464	42.7038

The AA of sea buckthorn, evaluated by the diameter of the inhibition zone for *Bacillus pumilus*, was 3.70–15.91 mm/g⁻¹ for whole sea buckthorn fruits and 13.33–26.67 mm/g⁻¹ for sea buckthorn purees.

It is known that the AA of fruits depends on their antioxidant activity [6,12,13,16,24,31]. Xiangqun Gao et al. [37,38] investigated the antioxidant activity of sea buckthorn and found that it depends on the content of phenolic substances and ascorbic acid, as well as the content of carotenoids. The authors mention that when sea buckthorn fruits ripen, their antioxidant activity changes depending on the correlation of these substances in berries.

Figures 2 and 3 show the areas of inhibition of *Bacillus pumilus* caused by sea buckthorn fruits and purees.

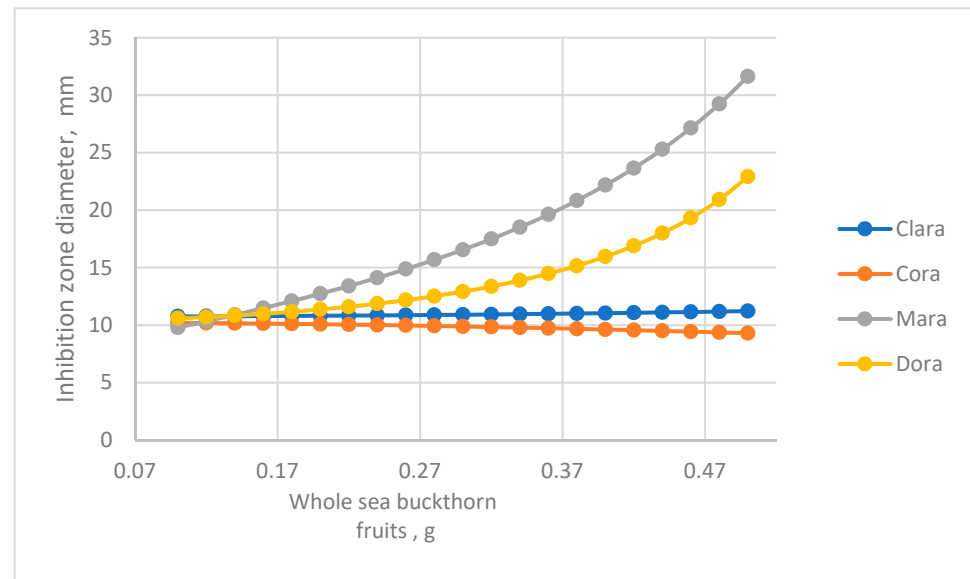


Figure 2. Areas of inhibition of the bacterium *Bacillus pumilus* caused by sea buckthorn fruits.

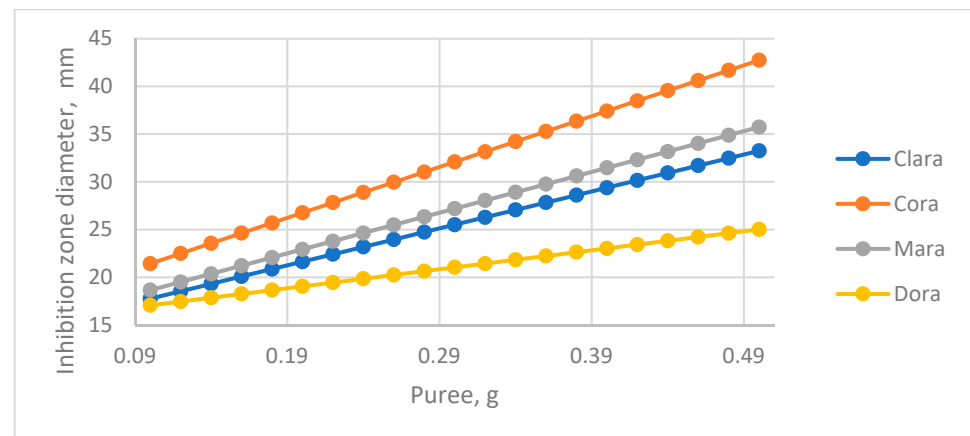


Figure 3. Areas of inhibition of the bacterium *Bacillus pumilus* caused by sea buckthorn purees.

The ascorbic acid content, the titratable acidity and the pH of the berries gave the possibility to identify the correlation between these components and the values of the diameter of the area of inhibition of bacteria that cause food poisoning.

4. Discussion

4.1. Physicochemical Analysis

Bal et al. [39] comparatively studied the chemical properties of sea buckthorn fruits. According to their results, the highest moisture content in pulp from berries is 84.9–97.6%

for the Indian sea buckthorn (TDM 2.4–15.1%) and the lowest is in varieties from Pakistan (20–32%; TDM 20–32%). Our research has shown that the TDM varies between 6.74 and 18.78%, which is in agreement with the previous researchers.

The TA and pH of the samples studied were also different. The TA in the investigated sea buckthorn cultivars was 3.22 ± 0.03 for Dora (lowest value) and 5.92 ± 0.12 for Mara (maximum value). There are differences in how fruits and vegetables are categorised based on pH. Sea buckthorn fruits are generally classified as a highly acid food with a pH of 3.70 [40]. Munkhbayar, D. et al. [41] reports that the pH of sea buckthorn was within 2.10–2.50. According to the values obtained in this study, the sea buckthorn fruits are within the pH range of 2.76–3.00 (Table 2).

4.2. Content of Biologically Active Substances

The average ascorbic acid content in berries of all the studied sea buckthorn cultivars was 199.34 mg/100 g, with a range of variation from 113.14 (Cora) to 278.71 mg/100 g (Mara). Ascorbic acid content values in fruits above the average (more than 200 mg/100 g) were also observed in the Dora cultivar. These values are significantly higher than in the fruits of gooseberry, cornel and lemon. The vitamin C content of sea buckthorn fruits ranges from 52.86 to 896 mg/100 g [19,42].

Sea buckthorn fruits at certain stages of development accumulate organic acids in the pulp. Beveridge et al. [32] notes that the organic acid of sea buckthorn fruits was composed of malic acid (6.30 mg/100 g), tartaric acid (5.55 mg/100 g), quinic acid (1.67 mg/100 g), citric acid (0.31 mg/100 g) and succinic acid (0.29 mg/100 g). Malic acid and tartaric acid were the major organic acids in sea buckthorn fruits and accounted for about 90% of the total organic acids. This is also confirmed by studies of the cultivars tested [43].

The most common organic acids are citric and malic acids. The content of organic acids in fruit pulp depends on the environmental factors and cultivation methods (temperature, light intensity, variety, rootstock, mineral nutrition, water availability, fruit load/pruning). In other cases, when the total organic acids in fruits are considered, an increase in their content during fruit development and ripening has been observed [44,45]. In the studied cultivars, there is a tendency to increase the concentration of malic and citric acids (responsible for the sour taste of the fruits) depending on the cultivar. These values reach the maximum value in the Mara cultivar and decrease in the Dora cultivar: Mara > Clara > Cora > Dora. The highest concentration of succinic acid was observed in the Clara variety (Table 3).

The authors of other studies report that malic and quinic acids are the main organic acids in sea buckthorn fruits and make up about 90% of all berry acids. In Russian sea buckthorn varieties, the TA is 2.1–3.2 g/100 mL, in the Finnish varieties it is 4.2–6.5 g/100 mL and in Chinese genotypes it is 3.5–9.1 g/100 mL [46,47].

Michalak, M et al. [48] notes that sea buckthorn is a rich source of carotenoids, including β -carotene. They can be arranged as follows: sea buckthorn oil > carrot oil > marigold oil > pumpkin seed oil. Another study [49] reported that the carotenoid content expressed as β -carotene content in sea buckthorn juice ranged from 50.63 mg/100 g to 93.63 mg/100 g; the highest content was in the Askola cultivar and the lowest was in Terhi. Beveridge et al. [5] reported trace amounts of total carotenoids in the seed oils of some sea buckthorn varieties ranging between 50 and 85 mg/100 g oil. Beveridge [50] reported a total carotenoid concentration of 41.1 mg/100 g in the seed oil of the cultivar Indian-Summer and also a wide range of total carotenoids contents from 330 to 1000 mg/100 g of oil, depending on plant subspecies or cultivar. A comparison of the carotenoid contents in seed oil showed substantial variation in the carotenoid content between different solvent extraction methods [51].

Other research and scientific studies report that the carotenoid content in sea buckthorn is in the range of 11–26.6 mg/100 g [52], 6–28 mg/100 g [49,50], 19.7 mg/100 g [51] or 242.0–325.0 mg/100 g [37,53,54].

4.3. Antimicrobial Activity of Sea Buckthorn Fruits and Purees

By calculating the Person coefficient, it was found that the antimicrobial activities of sea buckthorn fruits and purees are largely influenced by the chemical composition of the berries. Although different results were obtained between cultivars, this correlation is quite high. A very high correlation was found between chemical indicators and sea buckthorn antimicrobial activity:

For whole sea buckthorn fruits:

Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and CC}) = 0.7179 \dots 0.9791$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and AAC}) = 0.5738 \dots 0.9791$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and TDM}) = 0.7154 \dots 0.9791$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and TA}) = 0.9689 \dots 1.000$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and pH}) = -0.9280 \dots -0.9952$.

For sea buckthorn purees:

Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and CC}) = 0.7552 \dots 0.9940$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and AAC}) = 0.5174 \dots 0.9577$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and TDM}) = 0.7174 \dots 0.9577$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and TA}) = 0.7061 \dots 1.000$; Pearson coefficient $P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and pH}) = -0.7720 \dots -0.9582$.

The Pearson coefficient ($P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and pH})$) has negative values, which shows us that the interdependence between these indicators is inversely proportional.

The best indices at different fruit weights and time dynamics of change in the size of inhibition zones (mm) can be attributed to the varieties Mara and Dora (Figure 2). The best indices of inhibition zones (mm) for puree can be attributed to the varieties Kora and Mara (Figure 3).

The antiviral, antibacterial and antifungal properties of sea buckthorn are reported in several studies (Table 6).

Table 6. The antiviral, antibacterial and antifungal properties of sea buckthorn.

Properties	Investigation Method	Target Microorganisms	Source
Antibacterial activity	Standard disc diffusion method	<i>Staphylococcus aureus</i>	Muhammad Imran Qadir et al. [55]
Antimicrobial		<i>Streptococcus gordonii</i> , <i>Porphyromonas gingivalis</i> , <i>Actinomyces viscosus</i> and <i>Candida albicans</i> .	Smida et al. [56]
Antimicrobial activity		<i>Candida albicans</i> , <i>Pichia jadinii</i> , <i>Bacillus subtilis</i> and <i>Staphylococcus aureus</i>	Jeong, J.H et al. [57]
Antiviral, antibacterial activity, fungal strains	Inhibition zone diameter, IS (50)	<i>Staphylococcus aureus</i> , <i>Haemophilus influenzae</i> , <i>Streptococcus agalactiae</i> , <i>Streptococcus pyogenes</i> , <i>Streptococcus pneumoniae</i>	Heikki Kallio [18]
Antibacterial property	Diffusion method, Minim inhibition concentration (MIC)	<i>Escherichia coli</i> , <i>Salmonella enterica</i> , <i>Yersinia enterocolitica</i> , <i>Bacillus thuringiensis</i> , <i>Listeria monocytogenes</i> , <i>Staphylococcus aureus</i>	Ivanišová, E. et al. [52]
Antibacterial property and fungal strains		Gram-positive bacteria (<i>Bacillus cereus</i> , <i>Enterococcus durans</i> , <i>Enterococcus faecalis</i> , <i>Staphylococcus aureus</i>), Gram-negative bacteria (<i>Aeromonas hydrophila</i> , <i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> , <i>Pseudomonas fluorescens</i> , <i>Pichia jadinii</i> , <i>Salmonella enterica</i> , <i>Salmonella typhimurium</i> , <i>Yersinia enterocolitica</i>) and yeast (<i>Candida albicans</i>)	Jeong, J.H et al. [57]; Michel et al. [37]; Upadhyay et al. [42]; Richa Arora [58]
Antimicrobial activity		<i>Escherichia coli</i>	Giedre Kasparaviciene [59]
Antimicrobial activity	Inhibition zone, minimum inhibition concentration (MIC)	<i>Staphylococcus aureus</i> , <i>Bacillus subtilis</i> , <i>Salmonella Typhimurium</i> , <i>Escherichia coli</i> , <i>Candida albicans</i>	Sandulachi et al. [60]

Carotenoids are among the most common natural pigments, and more than 600 different compounds have been characterised until now, with β -carotene as the most promi-

nent [61]. Various scientific research and studies show that sea buckthorn has remarkable antimicrobial antioxidant properties [62]. Information on the antioxidant properties of sea buckthorn carotene is reported by the researchers Oguz Merhan [63] and Andrea Mendelová [49]. Carotenoids can inhibit active radicals by transferring electrons, giving hydrogen atoms to radicals or attaching to radicals [64]. The activity of carotenoids as antioxidants also depends on their interaction with other antioxidants, such as vitamins E and C [65]. There are three isomers of carotene, alpha, beta and gamma, with the beta isomer being most active [66]. The mechanism of the microbial action of berries is diverse and can act by destroying the cell membrane, inhibiting DNA and preventing protein biosynthesis, etc., [62]. The antioxidant activity is more potent with extracted sea buckthorn oil because of higher carotenoid levels. The results from [60] indicate that the antioxidant activity of sea buckthorn oil depends on the extraction methods and heat treatments used. Sea buckthorn could be used as a natural replacement for synthetic additives and for food products with functional properties [60,67].

5. Conclusions

In the process of preliminary cultivar trials previously conducted by the authors, four sea buckthorn cultivars grown in the Republic of Moldova—Clara, Dora, Cora and Mara—were selected for use in industrial processing. The productivity, carotenoid content and ascorbic acid content, as well as the total content of dry matter, titratable acidity and pH of berries was evaluated in this study. Significant amounts of ascorbic acid and carotenoids were recorded in these cultivars. The basic composition of organic acids was also determined. The sea buckthorn cultivars tested were found to have different CC (1.79–48.92 mg/100 g), AAC (74.36–373.38 mg/100 g), OA (malic acid 5.8–13.4 mg/100 g, citric acid 0.08–0.32 mg/100 g, succinic acid 0.03–1.1 mg/100 g), TDM (16.71–24.54%), TA (2.1–8.76%) and pH values (2.73–3.00). It was found that sea buckthorn is a rich source of biologically active compounds, and its antimicrobial activity, proved by a number of authors, was also confirmed in this study. The ascorbic acid content, titratable acidity and pH of the berries gave the possibility to identify the correlation between these components and the values of the diameter of the area of inhibition of bacteria that cause food poisoning. The antimicrobial activity of sea buckthorn fruit and puree on *Bacillus pumilus* was also investigated. There was a very high interdependence between the chemical indicators of sea buckthorn and the sea buckthorn's antibacterial activity.

The Pearson coefficient ($P_c = f(\text{AA } \textit{Bacillus pumilus} \text{ and PCI})$) for the tested sea buckthorn fruits formed the following sequence: Dora > Mara > Cora $\geq$ Clara; for the respective sea buckthorn purees the sequence was: Cora > Mara > Dora $\geq$ Clara.

Sea buckthorn fruits are rich in biologically active ingredients with high antimicrobial capacity. The results of the study showed that the studied sea buckthorn berries may be a raw material for developing functional foods and nutraceutical products rich in compounds with high biological activity. Thus, the rich chemical composition of sea buckthorn fruits can be used in the food industry for food fortification.

Author Contributions: Conceptualisation, E.S. and N.N.; Data curation, E.S. and N.N.; Formal analysis, E.S., N.N. and A.M.; Funding acquisition, S.P., A.M. and I.R.; Investigation, N.N., I.S., I.D. and O.B.; Methodology, E.S., N.N., A.M., I.D., O.B., S.P., I.R.; Resources, N.N., A.M., S.P. and E.S.; Software, E.S. and N.N.; Supervision, E.S., N.N. and A.M.; Validation, N.N., E.S., A.M., S.P., I.R., I.D., I.S. and O.B.; Visualisation, E.S. and N.N.; Writing—original draft, E.S. and N.N.; Writing—review and editing N.N., S.P. and I.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Agency for Research and Development, Moldova State project 20.80009.5107.13 “Development technology of sea buckthorn production in the ecological system and processing of fruits and biomass”.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

Conflicts of Interest: The authors declare no conflicts of interest.

References

- Small, E.; Catling, P.; Li, T. Blossoming treasures of biodiversity: 5. Sea Buckthorn (*Hippophae rhamnoides*)—An ancient crop with modern virtues. *Biodiversity* **2002**, *3*, 25–27. [\[CrossRef\]](#)
- Dong, R.; Su, J.; Nian, H.; Shen, H.; Zhai, X.; Xin, H.; Qin, L.; Han, T. Chemical Fingerprint and Quantitative Analysis of Flavonoids for Quality Control of Sea Buckthorn Leaves by HPLC and UHPLC-ESI-QTOF-MS. *J. Funct. Foods* **2017**, *37*, 513–522. [\[CrossRef\]](#)
- Tian, Y.; Liimatainen, J.; Alanne, A.-L.; Lindstedt, A.; Liu, P.; Sinkkonen, J.; Kallio, H.; Yang, B. Phenolic Compounds Extracted by Acidic Aqueous Ethanol from Berries and Leaves of Different Berry Plants. *Food Chem.* **2017**, *220*, 266–281. [\[CrossRef\]](#)
- Sharma, U.; Sharma, K.; Sharma, N.; Sharma, A.; Singh, H.; Sinha, A.K. Microwave-Assisted Efficient Extraction of Different Parts of *Hippophae rhamnoides* for the Comparative Evaluation of Antioxidant Activity and Quantification of Its Phenolic Constituents by Reverse-Phase High-Performance Liquid Chromatography (RP-HPLC). *J. Agric. Food Chem.* **2008**, *56*, 374–379. [\[CrossRef\]](#)
- Beveridge, T.; Li, T.; Oomah, B.; Smith, A. Sea Buckthorn Products: Manufacture and Composition. *J. Agric. Food Chem.* **1999**, *47*, 3480–3488. [\[CrossRef\]](#) [\[PubMed\]](#)
- Jaśniewska, A.; Diowks, A. Wide Spectrum of Active Compounds in Sea Buckthorn (*Hippophae rhamnoides*) for Disease Prevention and Food Production. *Antioxidants* **2021**, *10*, 1279. [\[CrossRef\]](#) [\[PubMed\]](#)
- Tudor, C.; Bohn, T.; Iddir, M.; Dulf, F.V.; Focșan, M.; Rugină, D.O.; Pinte, A. Sea Buckthorn Oil as a Valuable Source of Bioaccessible Xanthophylls. *Nutrients* **2019**, *12*, 76. [\[CrossRef\]](#) [\[PubMed\]](#)
- Ercisli, S.; Orhan, E.; Ozdemir, O.; Sengul, M. The Genotypic Effects on the Chemical Composition and Antioxidant Activity of Sea Buckthorn (*Hippophae rhamnoides* L.) Berries Grown in Turkey. *Sci. Hortic.* **2007**, *115*, 27–33. [\[CrossRef\]](#)
- Zhang, W.; Yan, J.; Duo, J.; Ren, B.; Guo, J. Preliminary study of biochemical constitutions of berry of sea buckthorn growing in Shanxi province and their changing trend. In Proceedings of the International Symposium on Sea Buckthorn (*H. rhamnoides* L.), Xi'an, China, 19–23 October 1989; pp. 96–105.
- Solà Marsinach, M.; Cuenca, A.P. The Impact of Sea Buckthorn Oil Fatty Acids on Human Health. *Lipids Health Dis.* **2019**, *18*, 145. [\[CrossRef\]](#)
- Sandulachi, E.; Bulgaru, V.; Ghendov-Mosanu, A.; Sturza, R. Controlling the Risk of Bacillus in Food Using Berries. *Food Nutr. Sci.* **2021**, *12*, 557–577. [\[CrossRef\]](#)
- Sandulachi, E.; Cojocari, D.; Balan, G.; Popescu, L.; Ghendov-Mosanu, A.; Sturza, R. Antimicrobial Effects of Berries on *Listeria monocytogenes*. *Food Nutr. Sci.* **2020**, *11*, 873–886. [\[CrossRef\]](#)
- Sturza, R.; Sandulachi, E.; Cojocari, D.; Balan, G.; Popescu, L.; Ghendov-Mosanu, A. Antimicrobial properties of berry powders in cream cheese. *J. Eng. Sci.* **2019**, *26*, 125–136.
- Cojocari, D.; Sturza, R.; Sandulachi, E.; Macari, A.; Balan, G.; Ghendov-Mosanu, A. Inhibiting of accidental pathogenic microbiota in meat products with berry powders. *J. Eng. Sci.* **2019**, *26*, 114–122.
- Tyagi, N.; Singh, A.; Kohli, K. New Insights towards Implications of Sea Buckthorn Oil in Human Health: A Review. *Int. J. Pharmacogn. Chin. Med.* **2018**, *4*, 1204–1208.
- Mohan Gupta, S.; Gupta, A.K.; Ahmed, Z. Antibacterial and Antifungal Activity in Leaf, Seed Extract and Seed Oil of Seabuckthorn (*Hippophae Salicifolia* D. Don) Plant. *J. Plant Pathol. Microbiol.* **2011**, *2*, 1–4. [\[CrossRef\]](#)
- Schubertová, S.; Krepšová, Z.; Janotková, L.; Potočnáková, M.; Kreps, F. Exploitation of Sea Buckthorn Fruit for Novel Fermented Foods Production: A Review. *Processes* **2021**, *9*, 749. [\[CrossRef\]](#)
- Kallio, H.; Yang, W.; Liu, P.; Yang, B. Proanthocyanidins in Wild Sea Buckthorn (*Hippophae rhamnoides*) Berries Analyzed by Reversed-Phase, Normal-Phase, and Hydrophilic Interaction Liquid Chromatography with UV and MS Detection. *J. Agric. Food Chem.* **2014**, *62*, 7721–7729. [\[CrossRef\]](#)
- Teleszko, M.; Wojdyło, A.; Rudzińska, M.; Oszmiański, J.; Golis, T. Analysis of Lipophilic and Hydrophilic Bioactive Compounds Content in Sea Buckthorn (*Hippophae rhamnoides* L.) Berries. *J. Agric. Food Chem.* **2015**, *63*, 4120–4129. [\[CrossRef\]](#)
- Criste, A.; Urcan, A.C.; Bunea, A.; Pripon Furtuna, F.R.; Olah, N.K.; Madden, R.H.; Corcionivoschi, N. Phytochemical Composition and Biological Activity of Berries and Leaves from Four Romanian Sea Buckthorn (*Hippophae rhamnoides* L.) Varieties. *Molecules* **2020**, *25*, 1170. [\[CrossRef\]](#)
- Gatlan, A.-M.; Gutt, G. Sea Buckthorn in Plant Based Diets. An Analytical Approach of Sea Buckthorn Fruits Composition: Nutritional Value, Applications, and Health Benefits. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8986. [\[CrossRef\]](#)
- Terechuk, L.; Starovoytova, K.; Ivanova, S.; Sergeeva, I. Obtaining Functional Products from Sea Buckthorn Berries. In Proceedings of the 2nd International Conference on Education Science and Social Development (ESSD 2019), Changsha, China, 20–21 July 2019; Atlantis Press: Changsha, China, 2019.
- Yang, B.; Kallio, H.P. Fatty Acid Composition of Lipids in Sea Buckthorn (*Hippophae rhamnoides* L.) Berries of Different Origins. *J. Agric. Food Chem.* **2001**, *49*, 1939–1947. [\[CrossRef\]](#)

24. Yue, X.-F.; Shang, X.; Zhang, Z.-J.; Zhang, Y.-N. Phytochemical Composition and Antibacterial Activity of the Essential Oils from Different Parts of Sea Buckthorn (*Hippophae rhamnoides* L.). *J. Food Drug Anal.* **2017**, *25*, 327–332. [CrossRef]
25. Catalog of Plant Varieties for Year 2023. Available online: https://cstsp.md/uploads/files/Registru_2023_Tipar_Gray.pdf (accessed on 5 January 2024).
26. Latimer, G.W. (Ed.) *Official Methods of Analysis of AOAC International*, 22nd ed.; Oxford University Press: New York, NY, USA, 2023.
27. Siriengkawut, W. Electrochemical Analysis of Ascorbic Acid in Commercial Fruit Juices and Drinks. *Asian J. Chem.* **2014**, *26*, 6487–6491. [CrossRef]
28. Ferey, L.; Delaunay, N. Food Analysis on Electrophoretic Microchips. *Sep. Purif. Rev.* **2016**, *45*, 193–226. [CrossRef]
29. Wang, M.; Qu, F.; Shan, X.-Q.; Lin, J.-M. Development and Optimization of a Method for the Analysis of Low-Molecular-Mass Organic Acids in Plants by Capillary Electrophoresis with Indirect UV Detection. *J. Chromatogr. A* **2003**, *989*, 285–292. [CrossRef] [PubMed]
30. Rovio, S.; Sirén, K.; Sirén, H. Application of Capillary Electrophoresis to Determine Metal Cations, Anions, Organic Acids, and Carbohydrates in Some Pinot Noir Red Wines. *Food Chem.* **2011**, *124*, 1194–1200. [CrossRef]
31. Ghendov-Mosanu, A.; Netreba, N.; Balan, G.; Cojocari, D.; Boestean, O.; Bulgaru, V.; Gurev, A.; Popescu, L.; Deseatnicova, O.; Resitca, V.; et al. Effect of Bioactive Compounds from Pumpkin Powder on the Quality and Textural Properties of Shortbread Cookies. *Foods* **2023**, *12*, 3907. [CrossRef] [PubMed]
32. Beveridge, T.; Harrison, J.E.; Drover, J. Processing Effects on the Composition of Sea Buckthorn Juice from *Hippophae rhamnoides* L. Cv. Indian Summer. *J. Agric. Food Chem.* **2002**, *50*, 113–116. [CrossRef] [PubMed]
33. Hudzicki, J. Kirby-Bauer Disk Diffusion Susceptibility Test Protocol. *Am. Soc. Microbiol.* **2016**, *15*, 55–63.
34. Valgas, C.; De Souza, S.; Smânia, E. Screening methods to determine antibacterial activity of natural products. *Braz. J. Microbiol.* **2007**, *38*, 369–380. [CrossRef]
35. Clewer, A.; Scarisbrick, D. *Practical Statistics and Experimental Design for Plant and Crop Science*; John Wiley & Sons Ltd.: Chichester, UK, 2001.
36. Babeanu, N.; Cimpoeș, D.; Lica, D.; Racul, A. *Biometrie*; Ed. UASM: Chisinau, Moldova, 2012.
37. Michel, T.; Destandau, E.; Le Floch, G.; Lucchesi, M.E.; Elfakir, C. Antimicrobial, Antioxidant and Phytochemical Investigations of Sea Buckthorn (*Hippophaë rhamnoides* L.) Leaf, Stem, Root and Seed. *Food Chem.* **2012**, *131*, 754–760. [CrossRef]
38. Gao, X.; Ohlander, M.; Jeppsson, N.; Björk, L.; Trajkovski, V. Changes in Antioxidant Effects and Their Relationship to Phytonutrients in Fruits of Sea Buckthorn (*Hippophae rhamnoides* L.) during Maturation. *J. Agric. Food Chem.* **2000**, *48*, 1485–1490. [CrossRef] [PubMed]
39. Bal, L.; Meda, V.; Naik, S.; Satya, S. Sea buckthorn berries: A potential source of valuable nutrients for nutraceuticals and cosmeceuticals. *Food Res. Int.* **2011**, *44*, 1718–1727. [CrossRef]
40. Classification of Food on Basis of Acidity. Available online: <https://foodtechnotes.com/2020/10/27/classification-of-food-on-basis-of-acidity/> (accessed on 30 December 2023).
41. Munkhbayer, D.; Ariuntungalag, J.; Delgersuuri, G.; Badamkhand, D. Enzymatic Technology for Sea Buckthorn Oil Extraction and Its Biochemical Analysis. *Mong. J. Chem.* **2014**, *15*, 62–65. [CrossRef]
42. Upadhyay, N.; Yogendra Kumar, M.; Gupta, A. Antioxidant, Cytoprotective and Antibacterial Effects of Sea Buckthorn (*Hippophae rhamnoides* L.) Leaves. *Food Chem. Toxicol.* **2010**, *48*, 3443–3448. [CrossRef] [PubMed]
43. Lee, Y.H.; Jang, H.J.; Park, K.H.; Kim, S.H.; Kim, J.K.; Kim, J.C.; Jang, T.S.; Kim, K.H. Phytochemical Analysis of the Fruits of Sea Buckthorn (*Hippophae rhamnoides*): Identification of Organic Acid Derivatives. *Plants* **2021**, *10*, 860. [CrossRef]
44. Famiani, F.; Bonghi, C.; Chen, Z.-H.; Drincovich, M.; Farinelli, D.; Lara, M.; Proietti, S.; Rosati, A.; Vizzotto, G.; Walker, R. Stone Fruits: Growth and Nitrogen and Organic Acid Metabolism in the Fruits and Seeds—A Review. *Front. Plant Sci.* **2020**, *11*, 572–601. [CrossRef]
45. Famiani, F.; Battistelli, A.; Moscatello, S.; Cruz-Castillo, J.; Walker, R. The Organic Acids That Are Accumulated in the Flesh of Fruits: Occurrence, Metabolism and Factors Affecting Their Contents—A Review. *Rev. Chapingo Ser. Hortic.* **2015**, *21*, 97–128. [CrossRef]
46. Ma, Z.; Cui, Y.; Feng, G. Studies on the fruit character and biochemical compositions of some forms within Chinese sea buckthorn (*Hippophae rhamnoides* subsp. *sinensis*). In Proceedings of the International Symposium on Sea Buckthorn (*H. rhamnoides* L.), Xi'an, China, 19–23 October 1989; pp. 106–113.
47. Kallio, K.; Yang, B.; Tahvonen, R.; Hakala, M. Composition of sea buckthorn berries of various origins. In Proceedings of the International Symposium on Sea Buckthorn (*Hippophae rhamnoides* L.), Beijing, China, 29 August 1999.
48. Michalak, M.; Paradowska, K.; Zielińska, A. Selected plant oils as a source of carotenoids for the applications in cosmetology. *Postępy Fitoter.* **2018**, *1*, 10–17.
49. Mendelová, A.; Mendel, L.; Czako, P.; Mareček, J. Evaluation of Carotenoids, Polyphenols Content and Antioxidant Activity in the Sea Buckthorn Fruit. *Potravin. Slovak J. Food Sci.* **2016**, *10*, 59–64. [CrossRef]
50. Beveridge, T. Chemical composition and some physical properties. In *Sea Buckthorn (Hippophaë rhamnoides L.): Production and Utilization*; NRC Research Press: Ottawa, ON, Canada, 2003; pp. 79–88.
51. Yakimishen, R.; Cenkowski, S.; Muir, W. Oil Recoveries from Sea Buckthorn Seeds and Pulp. *Appl. Eng. Agric.* **2005**, *21*, 1047–1055. [CrossRef]

52. Ivanišová, E.; Blašková, M.; Terentjeva, M.; Grygorieva, O.; Vergun, O.; Brindza, J.; Kačániová, M. Biological Properties of Sea Buckthorn (*Hippophae rhamnoides* L.) Derived Products. *Acta Sci. Pol. Technol. Aliment.* **2020**, *19*, 195–205. [[PubMed](#)]
53. Lõugas, T. *Study on Physico-Chemical Properties and Some Bioactive Compounds of Sea Buckthorn (Hippophae rhamnoides L.)*; Thesis on Natural and Exact Sciences; TUT Press: Tallinn, Estonia, 2006.
54. Kumar, R.; Kumar, G.P.; Chaurasia, O.; Bala Singh, S. Phytochemical and Pharmacological Profile of Seabuckthorn Oil: A Review. *Res. J. Med. Plant* **2011**, *5*, 491–499. [[CrossRef](#)]
55. Qadir, M.; Abbas, K.; Younus, A.; Shaikh, R. Report—Antibacterial Activity of Sea Buckthorn (*Hippophae rhamnoides* L.) against Methicillin Resistant Staphylococcus Aureus (MRSA). *Pak. J. Pharm. Sci.* **2016**, *29*, 1711–1713. [[PubMed](#)]
56. Smida, I.; Pentelescu, C.; Pentelescu, O.; Sweidan, A.; Oliviero, N.; Meuric, V.; Martin, B.; Colceriu, L.; Bonnaure-Mallet, M.; Tamanai-Shacoori, Z. Benefits of Sea Buckthorn (*Hippophae rhamnoides*) Pulp Oil-based Mouthwash on Oral Health. *J. Appl. Microbiol.* **2019**, *126*, 1594–1605. [[CrossRef](#)] [[PubMed](#)]
57. Jeong, J.H. Antioxidant and Antimicrobial Activities of Extracts from a Medicinal Plant, Sea Buckthorn. *J. Korean Soc. Appl. Biol. Chem.* **2009**, *53*, 33–38.
58. Richa, A. Antimicrobial Activity of Seed, Pomace and Leaf Extracts of Sea Buckthorn (*Hippophae rhamnoides* L.) against Foodborne and Food Spoilage Pathogens. *Afr. J. Biotechnol.* **2012**, *11*, 10424–10430. [[CrossRef](#)]
59. Kasparaviciene, G.; Briedis, V.; Ivanauskas, L. Influence of sea buckthorn oil production technology on its antioxidant activity. *Medicina* **2004**, *40*, 753–757.
60. Sandulachi, E.; Macari, A.; Cojocari, D.; Balan, G.; Popa, S.; Turculet, N.; Ghendov-Mosanu, A.; Sturza, R. Antimicrobial properties of sea buckthorn grown in the republic of moldova. *J. Eng. Sci.* **2022**, *29*, 164–175. [[CrossRef](#)]
61. Stahl, W.; Sies, H. Antioxidant Activity of Carotenoids. *Mol. Asp. Med.* **2003**, *24*, 345–351. [[CrossRef](#)]
62. Shah, R.K.; Idate, A.; Sharma, P. Review on Antimicrobial Properties of Sea Buckthorn *Hippophae rhamnoides* L. *Int. J. All Res. Educ. Sci. Methods* **2020**, *8*, 1590–1599.
63. Merhan, O. The Biochemistry and Antioxidant Properties of Carotenoids. In *Carotenoids*; Cvetkovic, D.J., Nikolic, G.S., Eds.; InTech: Atyrau, Kazakhstan, 2017.
64. Kopsell, D. Accumulation and Bioavailability of Dietary Carotenoids in Vegetable Crops. *Trends Plant Sci.* **2006**, *11*, 499–507. [[CrossRef](#)] [[PubMed](#)]
65. Gammone, M.; Riccioni, G.; D’Orazio, N. Marine Carotenoids against Oxidative Stress: Effects on Human Health. *Mar. Drugs* **2015**, *13*, 6226–6246. [[CrossRef](#)]
66. Clark, S. *xPharm: The Comprehensive Pharmacology Reference*; Elsevier: Amsterdam, The Netherlands, 2007.
67. Šnē, E.; Galoburda, R.; Segliņa, D. Sea Buckthorn Vegetative Parts—A Good Source of Bioactive Compounds. *Proc. Latv. Acad. Sci. Sect. B Nat. Exact Appl. Sci.* **2013**, *67*, 101–108. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.