Scientific Bulletin. Series F. Biotechnologies, Vol. XXVI, No. 1, 2022
ISSN 2285-1364, CD-ROM ISSN 2285-5521, ISSN Online 2285-1372, ISSN-L 2285-1364

STABILIZATION OF SEA BUCKTHORN (*Elaeagnus rhamnoides*) TURBID JUICES

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Abstract

This paper reviews the technological solutions used to stabilize the sea buckthorn (Elaeagnus rhamnoides, syn. Hippophae rhamnoides) juice. Sea buckthorn is a nutraceutical crop of growing interest due to the health benefits of its berries active ingredients - essential (unsaturated) fatty acids, vitamins, antioxidants, and minerals. The turbid juice produced from the whole berries without enzymatic clearance has a higher biological value due to the extraction of the main active ingredients. However, the turbid juice made from sea buckthorn berries has poor physical and chemical stability. The lipids from berry pulp, rich in monounsaturated palmitoleic acid (16∶1n-7), separate from juices and are prone to rapid oxidation. Syneresis also occurs due to the low water-holding ability of the pulp polysaccharides. Oxidation reduces the content of the antioxidant (pro) vitamins. Stabilization is done by physical homogenization and/or utilization of additives with emulsification and/or antioxidant characteristics. The paper analyzes and discusses the advantages and drawbacks of the existing solutions.

***Key words**: sea buckthorn, turbid juice, syneresis, oxidation, stabilization, homogenization, additives.*

INTRODUCTION

Sea buckthorn, *Elaeagnus* (synonym *Hippophae*) *rhamnoides* (L.) A. Nelson is a thorny deciduous shrub recently domesticated (Kalia et al., 2011). Long-period sea buckthorn berries were harvested from nature (Yang et al., 2009). Domestication and establishment of orchards with this robust shrub tree were driven by its ecologic (Constandache et al., 2016) and economic importance (Gatlan & Gutt, 2021).

The ecologic importance of sea buckthorn results from its ability to colonize and stabilize marginal lands, including those from cold and dry areas or reclaimed spoil mines (Baig et al., 2021; Li & Schroeder, 1996; Zhao et al., 2013). The ability of sea buckthorn to grow well in poor soil is directly related to this robust shrub being both an actinorhizal plant and an endomycorrhizal plant (Zhou et al., 2017). As an actinorhizal plant, sea buckthorn has the ability to form symbiotic N2-fixing nodules with actinomycetes from *Frankia* genera (Diagne et al., 2013). The formation of symbiosis with mycorrhizae fungi supports phosphorus acquisition from immobile soil sources and the development of N2-fixing nodules and other beneficial rhizobacteria (Yang et al., 2018).

The economic importance of the sea buckthorn results from the high content of its fruits and leaves in bioactive ingredients - (pro)vitamins, essential (poly)unsaturated fatty acids, and antioxidant phytonutrients (Ren et al., 2020).

Due to its high content in healthy related compounds, sea buckthorn has been utilized for millennia as a nutraceutical/medicinal plant in Europe, China, and India (Suryakumar & Gupta, 2011; Wani et al., 2016).

Sea buckthorn leaves are occasionally used to prepare healthy infusions. The sea buckthorn fruits (berries) are the main edible parts used for nutraceutical purposes. Because of their acidic taste and short shelf life, sea buckthorn berries are not consumed in a fresh state (Alexandrakis et al., 2014). Usually the berries are converted into turbid juice prepared from the flashy pulp/pericarp and in a seed oil preparation, obtained by the mechanical extraction of the edible oil from the seeds (Beveridge et al., 1999). The pomace is further used as a source for tocopherols and carotenoids, extracted with supercritical CO_2 (Kitrytė et al., 2017; Mihalcea et al., 2021), for the production of soluble dietary fiber (Hussain et al., 2021) or for recovery of natural lipophilic antioxidants (Patra et al., 2022).

Turbid juice needs stabilization because of its heterogeneous composition, including suspended microparticles and hydrophobic and hydrophilic soluble fractions. The turbid juice separated during storage in three phases, with the oily one on the upper surface and sedimented particles on the bottom (Beveridge et al., 1999). This work reviews the technological solutions used to stabilize the sea buckthorn turbid juice. Initially, we detail the technical problems associated with the composition of the turbid juice and its peculiar rheology. Further, we describe the physicomechanical processes used for turbid juice stabilization. We address the innovative solutions at the end of the paper, including those described in the published patents.

Active ingredients in the sea buckthorn turbid juice

The diverse agro-pedo-climatic conditions promote the accumulation of different bioactive compounds in sea buckthorn berries and leaves. Romanian cultivars, differentiated in a separate subspecies, *E.* (*H.*) *rhamnoides* subsp. *carpatica* accumulated in the berries five carotenoids, β-carotene, cis-β-carotene, β-cryptoxanthin, lutein, and zeaxanthin. The antioxidant activity of extract from these Romanian cultivars correlated well (r = 0.96) with the total flavonoids. The antibacterial activity against *Bacillus cereus* and *Pseudomonas aeruginosa* was higher in the sea buckthorn leaves (Criste et al., 2020).

The pulp oils from sea buckthorn cultivated in the Indian Himalayas had a high content of unsaturated fatty acid (65-75%), palmitoleic acid (16:1n-7), being the most abundant (32-53%) (Ranjith et al., 2006). The cultivars from *E.* (*H.*) *rhamnoides* subsp. *mongolica* that has been grown in Poland (51.59° N, 20.139° E) accumulated more monounsaturated fatty (palmitoleic, 16:1n-7; cis-vaccenic, C18:1 n-7; oleic C18:1 n-9) compared to polyunsaturated fatty acids (linoleic C18:2 n-6) (Teleszko et al., 2015). The berries from *E.* (*H.*) *rhamnoides* cultivated in Turkey accumulated a higher proportion of palmitoleic acid (47.3%) in the pulp (Cakir, 2004).

Despite variations due to subspecies - cultivars and the agro-pedoclimatic conditions, the presence in the pulp of a large amount of palmitoleic acid, in combination with different types of antioxidants, hydrophobic (carotenoids, flavonoids), and hydrophilic (hydroxycinnamic acids, ascorbic acid) is reported in all published studies - Table 1.

Table 1. Composition of the sea buckthorn fruit pulp

Active ingredients	Content ($mg.g^{-1}$ fresh weight)	Reference
Palmitoleic acid (16:1n-7)	2.54-15.92	(Yang & Kallio, 2001)
	4.27-16.7	(H. Kallio et al., 2002)
	2.64	(Cakir, 2004)
	4.95-23.76	(Dulf, 2012)
Total carotenoids	0.01 -0.18	(Andersson et al., 2009)
	0.02 -0.40	(Bal et al., 2011)
	0.17	(Pop et al., 2015)
Tocopherols	0.03-0.21	(Jiménez-Escrig & Sánchez-Muniz, 2000)
	0.06-0.14	(Heikki Kallio et al., 2002)
Flavonoids	3.54-10	(Bal et al., 2011)
	1.68-8.59	(Heinaaho & Julkunen-Tiitto, 2011)
Ascorbic acid	1.4-30	(Ranjith et al., 2006)
	0.25-25	(Bal et al., 2011)
Hydroxycinnamic acid	0.151-0.402	(Hajazimi et al., 2016)
Caffeic acid	0.03.6-0.087	
Ferulic acid	0.015-0.15	
p-Coumaric acid	0.10-0.265	

From 65 to 85% of the sea buckthorn berry flesh pulp is converted into turbid juice by (mechanical) squeezing the fruits. The turbid juice proved to have significant health benefits due to its high content in lipophilic and hydrophilic antioxidants and ω-7 palmitoleic acid (Ciesarová et al., 2020). For decades, sea buckthorn has been recognized for its effect on cardiovascular diseases and associated metabolic disorders (Olas, 2016). The immunomodulatory and anti-inflammatory effects were confirmed by several studies (Ren et al., 2020). Also, *in vitro* studies on transformed cells and *in vivo* studies on laboratory animals confirmed the anticancer activity of sea buckthorn (Olas et al., 2018).

Palmitoleic acid reduces the risk of type II diabetes by increasing insulin sensitivity (Hu et al., 2019). Serum palmitoleate acts as a lipokinin (Merino et al., 2016) and prevents harmful effects of metabolic syndrome (Talbot et al., 2014; Tricò et al., 2020). Sea buckthorn pulp oil enhanced the immunity of immunosuppressed mice due to a significant prebiotic effect on probiotic bacteria producing post-biotics, i.e., short-chain fatty acids (Zhang et al., 2021).

The carotenoids present in high quantity in turbid sea buckthorn juice synergize the palmitoleic effect on type II diabetes and metabolic syndrome. Sea buckthorn is an accessible source of carotenoids, especially zeaxanthin (Tudor et al., 2020). Carotenoids levels in serum were inversely correlated with type II diabetes (Marcelino et al., 2020) and metabolic syndrome (Beydoun et al., 2018; Matsumoto et al., 2021). This inverse correlation is higher for zeaxanthin (Sugiura et al., 2015). The hydrophilic antioxidants present in the sea buckthorn turbid juice are also active against type II diabetes (J.-S. Zheng et al., 2020) and metabolic syndrome (Liu et al., 2019). The anticancer activity of the sea buckthorn extracts was directly correlated with the level of ursolic acids (Grey et al., 2010), flavonol glycosides (Enkhtaivan et al., 2017) and flavonoid aglycones, including quercetin, isorhamnetin and kaempferol (Guo et al., 2017).

Recently, the low polarity fraction from sea buckhorn juice was reported to have low cytotoxicity for the normal cell and induce DNA damage apoptosis in cancer cells (Marciniak et al., 2021). This low polarity fraction from sea buckthorn juice contains triterpenoids, acylated triterpenoids, phospholipids and their derivatives, and saponins (Marciniak et al., 2021).

The lipophilic and hydrophilic antioxidants from sea buckthorn were reported to affect amyloid-beta (Aβ) levels directly. Therefore sea buckthorn could be efficient in Alzheimer's disease (Dong et al., 2020). The neuroprotective effect of sea buckthorn was also demonstrated against oxidative stress damage on neural tissue (Shivapriya et al., 2015), including the oxidative stress resulting from reperfusion following ischemia (Godeanu et al., 2020) and for iron-induced epilepsy (Ladol & Sharma, 2021).

Instability factors of the sea buckthorn turbid juice

This unique combination of active ingredients with high biological value also represents the source of an intrinsic instability - Figure 1.

The sea buckthorn turbid juice has a low thermal stability. This thermal instability is related to the instability of several components with high biological value, such as flavonoids, terpenoids, and carotenoids, and the dehydration reaction of soluble sugars in the presence of high-level ascorbic acids (Li et al., 2014). Polyphenols/hydroxycinnamic acids from the sea buckthorn juice tend to be more thermostable than carotenoids, flavonoids, and antioxidants (Ursache et al., 2017).

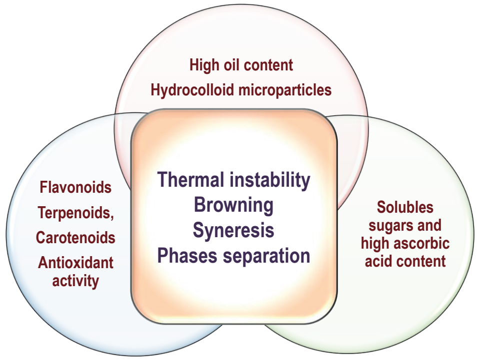

Figure 1. The instability factors of sea buckthorn turbid juice related to its specific composition

The formation of the 5-hydroxymethylfurfural (5-HMF) is associated with a non-enzymatic browning and a decrease in the level of ascorbic acid (Xu et al., 2015). HMF formation by dehydration of the soluble carbohydrates starts at a temperature lower than 60°C (Constantin et al., 2019). In sea buckthorn juice, HMF does not contribute to forming the Maillard type aroma/taste compounds and is considered a contaminant (Constantin et al., 2019; Rannou et al., 2016). The maximum allowed level of HMF in juice is 5 $mg.L^{-1}$ (Damasceno et al., 2008).

The formation of HMF could be associated with forming a more harmful contaminant, acrylamide (Constantin et al., 2019). However, the temperature promoting acrylamide formation is higher than 130°C (Constantin et al., 2019). The high oil content of the turbid juice, combined with the low water-holding ability of hydrocolloid microparticles, determine syneresis and phase separation (Beveridge et al., 1999).

Sea buckthorn turbid juice stabilization treatment

Several different mechanical treatments were proposed to stabilize the sea buckthorn turbid juice. The majority of these are inspired by the stabilization of the milk, a food system that is similar in terms of the presence of hydrophilic and lipophilic phases. Such treatments target the formation of a more stable suspension by generating smaller lipid droplets and reducing the particle dimension. However, sea buckthorn turbid juice is a much more complex system. It is not a simple emulsion; it is a suspoemulsion that includes both hydrophobic fractions and suspended particles. Each of the proposed treatments has some drawbacks.

Homogenization at 100 MPa in a piston homogenizer Panda PLUS 2000 (GEA Niro Soavi S.p.A., Parma, Italy) stabilizes the emulsion. Still, it generates a lighter and yellowish color that influences customers' acceptance (Aaby et al., 2020).

Better stabilization was obtained by using dynamic high-pressure microfluidization (DHPM) by using a Microfluidizer® (model M-110EH, Microfluidics Inc., Newton, MA, USA) (Abliz et al., 2021). The difference between a piston homogenizer and a microfluidization equipment is related to the dimensions of the space wherein the high shearing force occurs. The space is limited to a homogenizing valve that separates the high-pressure chamber from the atmospheric pressure in a piston homogenizer. In a Microfluidizer® processor, the space is a whole interaction microfluidics chamber, with walls treated with high hardness materials (i.e., zirconia or diamond). Microfluidizer® is expensive equipment with low capacity that is not yet suitable for the food industry (Guo et al., 2020). Pretreatment is necessary to avoid clogging

Various emulsifiers were combined with a piston homogenizer to enhance the stabilization of the sea buckthorn turbid juice suspoemulsion. The most effective stabilization agents were sodium caseinate- and sugar esters. However, the best stabilization agents also influenced the antioxidant activity (H. X. Zheng et al., 2020). This decrease in the antioxidant activity is because the carotenoids from sea buckthorn juice bind to the proteins (Aprodu et al., 2017; Dumitraşcu et al., 2016).

Table 2 summarizes the homogenization treatments (including the combined homogenization and emulsifiers) intended to stabilize the turbid sea buckthorn juice. The effects and drawbacks are presented.

Table 2. Homogenization treatment proposed for the stabilization of turbid sea buckthorn juice

Treatment	Effect	Drawbacks	Reference
Homogenization in a piston homogenizer, 100 MPa	The reduction of the oily droplets and the polysaccharides particles increased the stability of the suspoemulsion	Lighter and yellowish color – consumer perception	(Aaby et al., 2020)
Microfludization, up to 250 MPa, through a Z-shaped interaction chamber	Increased stability of the suspoemulsion, carotenoids released from droplets, higher antioxidant activity	Expensive equipment. technology is not yet ready for the food industry	(Abliz et al., 2021)
Emulsified agent + homogenization in a piston homogenizer	Increased stability of the suspoemulsions	Decreased the antioxidant activity due to conjugation	(H. X. Zheng et al., 2020)

Innovative approaches were proposed for the stabilization of the sea buckthorn turbid juice. The purified additives were replaced with different plant extracts – for example, the infusion from *Hibiscus* fruits (Heilscher, 1995). Other innovative approaches involved stabilization with extracts from sea buckthorn by-products - Figure 2.

Sea buckthorn berries juicing produce two types of by-products, leaves, and pomace. The fruits are very tightly bunched to the brunches, and the harvesting techniques generate significant amounts of leaves (Fu et al., 2014). The leaves have a higher antioxidant content than fruits (Olas, 2016).

The pomace is rich in pectin and antioxidants (Patra et al., 2022). Several patents claim utilization of the extracts from sea buckthorn by-products to stabilize the juice (Shi et al., 2019; Tian et al., 2018).

There are two main drawbacks of these solutions based on plant extracts. One is related to the taste - the plant extract enhances the astringency and the bitterness of the turbid juice. The other one is related to the low reproducibility of the stabilization process. This low reproducibility results from combining two highly variable products - the turbid juice and the plant extract (including the extract from the by-products of the sea buckthorn processing).

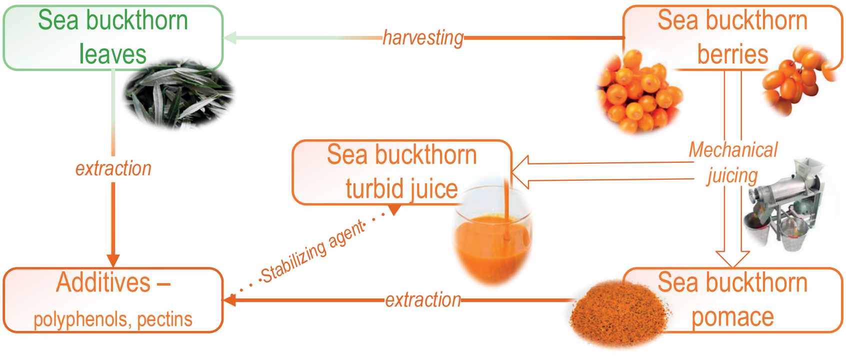

Figure 2. Illustration of the innovative approaches for stabilizing the sea buckthorn turbid juice by using extracts rich in polyphenols and/or pectin from sea buckthorn processing by-products

CONCLUSIONS

The sea buckthorn turbid juice is unstable and prone to browning and phase separation. Stabilization of the sea buckthorn turbid juice is done by physical homogenization and/or utilization of emulsifiers.

Innovative solutions involve the use as additives for stabilization of the extracts from the by-products of the sea buckthorn processing.

Complexity of the turbid juice suspoemulsion determine low reproducibility of the stabilization process.

Because of the drawbacks of the existing solutions, new approaches are needed for sea buckthorn turbid juice stabilization.

ACKNOWLEDGEMENTS

The research leading to these results has received funding from European Regional Development Fund (ERDF), the Competitiveness Operational Programme (POC), Axis 1, project POC-A1-A1.2.3-G-2015-P_40_352, My_SMIS 105684, “Sequential processes of closing the side streams from bioeconomy and innovative (bio)products resulting from it - SECVENT”, subsidiary project 2609/2020 - Nutri-GUT.

REFERENCES

Aaby, K., Martinsen, B. K., Borge, G. I. A., & Røen, D. (2020). Bioactive compounds and color of sea buckthorn (*Hippophae rhamnoides* L.) purees as affected by heat treatment and high-pressure homogenization. *International Journal of Food Properties, 23*(1), 651-664.

Abliz, A., Liu, J. F., Mao, L. K., Yuan, F., & Gao, Y. X. (2021). Effect of dynamic high pressure microfluidization treatment on physical stability, microstructure and carotenoids release of sea buckthorn juice. *Lwt-Food Science and Technology, 135*.

Alexandrakis, Z., Kyriakopoulou, K., Katsaros, G., Krokida, M., & Taoukis, P. (2014). Selection of Process Conditions for High Pressure Pasteurization of Sea Buckthorn Juice Retaining High Antioxidant Activity. *Food and Bioprocess Technology, 7*(11), 3226-3234.

Andersson, S. C., Olsson, M. E., Johansson, E., & Rumpunen, K. (2009). Carotenoids in sea buckthorn (*Hippophae rhamnoides* L.) berries during ripening and use of pheophytin a as a maturity marker. *Journal of Agricultural and Food Chemistry, 57*(1), 250-258.

Aprodu, I., Ursache, F.-M., Turturică, M., Râpeanu, G., & Stănciuc, N. (2017). Thermal stability of the complex formed between carotenoids from sea buckthorn (*Hippophae rhamnoides* L.) and bovine β-lactoglobulin. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 173*, 562-571.

Baig, S. M., Khan, A. A., Ali, A., Khan, M. Z., Ahmed, S., Shah, G. M., & Ali, G. (2021). Enhancing socioeconomic resilience and climate adaptation through value chain development of mountain products in Hindu Kush Himalayas. *Environment, Development and Sustainability, 23*(6), 8451-8473.

Bal, L. M., Meda, V., Naik, S. N., & Satya, S. (2011). Sea buckthorn berries: A potential source of valuable nutrients for nutraceuticals and cosmoceuticals. *Food Research International, 44*(7), 1718-1727.

Beveridge, T., Li, T. S. C., Oomah, B. D., & Smith, A. (1999). Sea Buckthorn Products: Manufacture and Composition. *Journal of Agricultural and Food Chemistry, 47*(9), 3480-3488.

Beydoun, M. A., Chen, X., Jha, K., Beydoun, H. A., Zonderman, A. B., & Canas, J. A. (2018). Carotenoids, vitamin A, and their association with the metabolic syndrome: a systematic review and meta-analysis. *Nutrition Reviews, 77*(1), 32-45.

Cakir, A. (2004). Essential oil and fatty acid composition of the fruits of *Hippophae rhamnoides* L. (Sea Buckthorn) and Myrtus communis L. from Turkey. *Biochemical Systematics and Ecology, 32*(9), 809-816.

Ciesarová, Z., Murkovic, M., Cejpek, K., Kreps, F., Tobolková, B., Koplík, R., Belajová, E., Kukurová, K., Daško, Ľ., Panovská, Z., Revenco, D., & Burčová, Z. (2020). Why is sea buckthorn (Hippophae rhamnoides L.) so exceptional? A review. *Food Research International, 133*, 109170.

Constandache, C., Peticila, A., Dinca, L., & Vasile, D. (2016). The usage of Sea Buckthorn (Hippophae Rhamnoides L.) for improving Romania's degraded lands. *AgroLife Scientific Journal, 5*(2), 50-58.

Constantin, O. E., Kukurová, K., Daško, Ľ., Stănciuc, N., Ciesarová, Z., Croitoru, C., & Râpeanu, G. (2019). Modelling Contaminant Formation during Thermal Processing of Sea Buckthorn Purée. *Molecules, 24*(8), 1571.

Criste, A., Urcan, A. C., Bunea, A., Pripon Furtuna, F. R., Olah, N. K., Madden, R. H., & Corcionivoschi, N. (2020). Phytochemical Composition and Biological Activity of Berries and Leaves from Four Romanian Sea Buckthorn (*Hippophae rhamnoides* L.) Varieties. *Molecules, 25*(5), 1170.

Damasceno, L. F., Fernandes, F. A. N., Magalhães, M. M. A., & Brito, E. S. (2008). Non-enzymatic browning in clarified cashew apple juice during thermal treatment: Kinetics and process control. *Food Chemistry, 106*(1), 172-179.

Diagne, N., Arumugam, K., Ngom, M., Nambiar-Veetil, M., Franche, C., Narayanan, K. K., & Laplaze, L. (2013). Use of Frankia and Actinorhizal Plants for Degraded Lands Reclamation. *BioMed Research International, 2013*, 948258.

Dong, K., Fernando, W. M. A. D. B., Durham, R., Stockmann, R., W. Jayatunga, D. P., & Jayasena, V. (2020). A role of sea buckthorn on Alzheimer's disease. *International Journal of Food Science & Technology, 55*(9), 3073-3081.

Dulf, F. V. (2012). Fatty acids in berry lipids of six sea buckthorn (Hippophae rhamnoides L., subspecies carpatica) cultivars grown in Romania. *Chemistry Central Journal, 6*(1), 106.

Dumitrașcu, L., Ursache, F. M., Stănciuc, N., & Aprodu, I. (2016). Studies on binding mechanism between carotenoids from sea buckthorn and thermally treated α-lactalbumin. *Journal of Molecular Structure, 1125*, 721-729.

Enkhtaivan, G., John, K. M., Pandurangan, M., Hur, J. H., Leutou, A. S., & Kim, D. H. (2017). Extreme effects of Seabuckthorn extracts on influenza viruses and human cancer cells and correlation between flavonol glycosides and biological activities of extracts. *Saudi Journal of Biological Sciences, 24*(7), 1646-1656.

Fu, L., Su, H., Li, R., & Cui, Y. (2014). Harvesting technologies for sea buckthorn fruit. *Engineering in Agriculture, Environment and Food, 7*(2), 64-69.

Gatlan, A. M., & Gutt, G. (2021). Sea Buckthorn in Plant Based Diets. An Analytical Approach of Sea Buckthorn Fruits Composition: Nutritional Value, Applications, and Health Benefits. *International Journal of Environmental Research and Public Health, 18*(17).

Godeanu, C. S., Costea, T., Ghica, M., Lupuliasa, D., & Gird, C. E. (2020). Evidence-based use of sea buckthorn fresh juice for patients with traumatic brain injury. A pilot study. *FARMACIA, 68*(3), 541-546.

Grey, C., Widén, C., Adlercreutz, P., Rumpunen, K., & Duan, R.-D. (2010). Antiproliferative effects of sea buckthorn (Hippophae rhamnoides L.) extracts on human colon and liver cancer cell lines. *Food Chemistry, 120*(4), 1004-1010.

Guo, R., Guo, X., Li, T., Fu, X., & Liu, R. H. (2017). Comparative assessment of phytochemical profiles, antioxidant and antiproliferative activities of Sea buckthorn (Hippophaë rhamnoides L.) berries. *Food Chemistry, 221*, 997-1003.

Guo, X., Chen, M., Li, Y., Dai, T., Shuai, X., Chen, J., & Liu, C. (2020). Modification of food macromolecules using dynamic high pressure microfluidization: A review. *Trends in food science & technology, 100*, 223-234.

Hajazimi, E., Landberg, R., & Zamaratskaia, G. (2016). Simultaneous determination of flavonols and phenolic acids by HPLC-CoulArray in berries common in the Nordic diet. *LWT, 74*, 128-134.

Heilscher, K. (1995). Germany Patent No. DE19549289C1.

Heinaaho, M., & Julkunen-Tiitto, R. (2011). Efficient extraction of flavonoids of sea buckthorn berries. *BioChemistry: An Indian Journal, 5*, 83-87.

Hu, W., Fitzgerald, M., Topp, B., Alam, M., & O'Hare, T. J. (2019). A review of biological functions, health benefits, and possible de novo biosynthetic pathway of palmitoleic acid in macadamia nuts. *Journal of Functional Foods, 62*, 103520.

Hussain, S., Sharma, M., & Bhat, R. (2021). Valorisation of sea buckthorn pomace by optimization of ultrasonic-assisted extraction of soluble dietary fibre using response surface methodology. *Foods, 10*(6), 1330.

Jiménez-Escrig, A., & Sánchez-Muniz, F. (2000). Dietary fibre from edible seaweeds: Chemical structure, physicochemical properties and effects on cholesterol metabolism. *Nutrition research, 20*(4), 585-598.

Kalia, R. K., Singh, R., Rai, M. K., Mishra, G. P., Singh, S. R., & Dhawan, A. K. (2011). Biotechnological interventions in sea buckthorn (Hippophae L.): current status and future prospects. *Trees, 25*(4), 559-575.

Kallio, H., Yang, B., Peippo, P., Tahvonen, R., & Pan, R. (2002). Triacylglycerols, Glycerophospholipids, Tocopherols, and Tocotrienols in Berries and Seeds of Two Subspecies (ssp. sinensis and mongolica) of Sea Buckthorn (Hippopha> ë rhamnoides). *Journal of Agricultural and Food Chemistry, 50*(10), 3004-3009.

Kallio, H., Yang, B. R., Peippo, P., Tahvonen, R., & Pan, R. L. (2002). Triacylglycerols, glycerophospholipids, tocopherols, and tocotrienols in berries and seeds of two subspecies (ssp sinensis and mongolica) of sea buckthorn (Hippophae rhamnoides). *Journal of Agricultural and Food Chemistry, 50*(10), 3004-3009.

Kitrytė, V., Povilaitis, D., Kraujalienė, V., Šulniūtė, V., Pukalskas, A., & Venskutonis, P. R. (2017). Fractionation of sea buckthorn pomace and seeds into valuable components by using high pressure and enzyme-assisted extraction methods. *LWT - Food Science and Technology, 85*, 534-538.

Ladol, S., & Sharma, D. (2021). The effects of Hippophae rhamnoides in neuroprotection and behavioral alterations against iron-induced epilepsy. *Epilepsy Research, 175*, 106695.

Li, H., Zhang, Q., S Bhadury, P., & Yang, S. (2014). Furan-type compounds from carbohydrates via heterogeneous catalysis. *Current Organic Chemistry, 18*(5), 547-597.

Li, T. S., & Schroeder, W. R. (1996). Sea buckthorn (Hippophae rhamnoides L.): a multipurpose plant. *HortTechnology, 6*(4), 370-380.

Liu, K., Luo, M., & Wei, S. (2019). The bioprotective effects of polyphenols on metabolic syndrome against oxidative stress: Evidences and perspectives. *Oxidative Medicine and Cellular Longevity, 2019*.

Marcelino, G., Machate, D. J., Freitas, K. d. C., Hiane, P. A., Maldonade, I. R., Pott, A., Asato, M. A., Candido, C. J., & Guimarães, R. d. C. A. (2020). β-Carotene: Preventive role for type 2 diabetes mellitus and obesity: A review. *Molecules, 25*(24), 5803.

Marciniak, B., Kontek, R., Żuchowski, J., & Stochmal, A. (2021). Novel bioactive properties of low-polarity fractions from sea-buckthorn extracts (Elaeagnus rhamnoides (L.) A. Nelson) – (in vitro). *Biomedicine & Pharmacotherapy, 135*, 111141.

Matsumoto, M., Suganuma, H., Ozato, N., Shimizu, S., Katashima, M., Katsuragi, Y., Mikami, T., Itoh, K., & Nakaji, S. (2021). Association between serum concentration of carotenoid and visceral fat. *Nutrients, 13*(3), 912.

Mihalcea, L., Turturică, M., Cucolea, E. I., Dănilă, G.-M., Dumitrașcu, L., Coman, G., Constantin, O. E., Grigore-Gurgu, L., & Stănciuc, N. (2021). CO2 Supercritical Fluid Extraction of Oleoresins from Sea Buckthorn Pomace: Evidence of Advanced Bioactive Profile and Selected Functionality. *Antioxidants, 10*(11), 1681.

Olas, B. (2016). Sea buckthorn as a source of important bioactive compounds in cardiovascular diseases. *Food and Chemical Toxicology, 97*, 199-204.

Olas, B., Skalski, B., & Ulanowska, K. (2018). The Anticancer Activity of Sea Buckthorn [Elaeagnus rhamnoides (L.) A. Nelson]. *Frontiers in Pharmacology, 9*.

Patra, B. R., Borugadda, V. B., & Dalai, A. K. (2022). Microwave-assisted extraction of sea buckthorn pomace and seed extracts as a proactive antioxidant to stabilize edible oils. *Bioresource Technology Reports, 17*, 100970.

Pop, E. A., Diaconeasa, Z. M., Fetea, F., Bunea, A., Dulf, F., Pintea, A., & Socaciu, C. (2015). Carotenoids, tocopherols and antioxidant activity of lipophilic extracts from sea buckthorn berries (*Hippophae rhamnoides*), apricot pulp and apricot kernel (*Prunus armeniaca*). *Bulletin UASVM Food Science and Technology, 72*(2), 169-176.

Ranjith, A., Kumar, K. S., Venugopalan, V. V., Arumughan, C., Sawhney, R. C., & Singh, V. (2006). Fatty acids, tocols, and carotenoids in pulp oil of three sea buckthorn species (*Hippophae rhamnoides, H. salicifolia*, and *H. tibetana*) grown in the Indian Himalayas. *Journal of the American Oil Chemists' Society, 83*(4), 359-364.

Rannou, C., Laroque, D., Renault, E., Prost, C., & Sérot, T. (2016). Mitigation strategies of acrylamide, furans, heterocyclic amines and browning during the Maillard reaction in foods. *Food Research International, 90*, 154-176.

Ren, R., Li, N., Su, C., Wang, Y., Zhao, X., Yang, L., Li, Y., Zhang, B., Chen, J., & Ma, X. (2020). The bioactive components as well as the nutritional and health effects of sea buckthorn. *RSC Advances, 10*(73), 44654-44671.

Shi, J., Xu, Z., Qian, J., Li, H., Zhou, T., & Zhou, L. (2019). CN108651786-A.

Shivapriya, S., Ilango, K., & Dubey, G. (2015). Evaluation of antioxidant and neuroprotective effect of *Hippophae rhamnoides* (L.) on oxidative stress induced cytotoxicity in human neural cell line IMR32. *Saudi Journal of Biological Sciences, 22*(5), 645-650.

Sugiura, M., Nakamura, M., Ogawa, K., Ikoma, Y., & Yano, M. (2015). High-serum carotenoids associated with lower risk for developing type 2 diabetes among Japanese subjects: Mikkabi cohort study. *BMJ Open Diabetes Research and Care, 3*(1), e000147.

Suryakumar, G., & Gupta, A. (2011). Medicinal and therapeutic potential of Sea buckthorn (*Hippophae rhamnoides* L.). *Journal of Ethnopharmacology, 138*(2), 268-278.

Talbot, N. A., Wheeler-Jones, C. P., & Cleasby, M. E. (2014). Palmitoleic acid prevents palmitic acid-induced macrophage activation and consequent p38 MAPK-mediated skeletal muscle insulin resistance. *Molecular and Cellular Endocrinology, 393*(1), 129-142.

Teleszko, M., Wojdyło, A., Rudzińska, M., Oszmiański, J., & Golis, T. (2015). Analysis of Lipophilic and Hydrophilic Bioactive Compounds Content in Sea Buckthorn (*Hippophaë rhamnoides* L.) Berries. *Journal of Agricultural and Food Chemistry, 63*(16), 4120-4129.

Tian, Z., Li, P., & Yu, H. (2018). CN111671783-A.

Tricò, D., Mengozzi, A., Nesti, L., Hatunic, M., Gabriel Sanchez, R., Konrad, T., Lalić, K., Lalić, N. M., Mari, A., & Natali, A. (2020). Circulating palmitoleic acid is an independent determinant of insulin sensitivity, beta cell function and glucose tolerance in non-diabetic individuals: A longitudinal analysis. *Diabetologia, 63*(1), 206-218.

Tudor, C., Bohn, T., Iddir, M., Dulf, F. V., Focşan, M., Rugină, D. O., & Pintea, A. (2020). Sea Buckthorn Oil as a Valuable Source of Bioaccessible Xanthophylls. *Nutrients, 12*(1), 76.

Ursache, F.-M., Ghinea, I. O., Turturică, M., Aprodu, I., Râpeanu, G., & Stănciuc, N. (2017). Phytochemicals content and antioxidant properties of sea buckthorn (*Hippophae rhamnoides* L.) as affected by heat treatment - Quantitative spectroscopic and kinetic approaches. *Food Chemistry, 233*, 442-449.

Wani, T. A., Wani, S., Ahmad, M., Ahmad, M., Gani, A., & Masoodi, F. (2016). Bioactive profile, health benefits and safety evaluation of sea buckthorn (Hippophae rhamnoides L.): A review. *Cogent Food & Agriculture, 2*(1), 1128519.

Xu, H., Hao, Q., Yuan, F., & Gao, Y. (2015). Non-enzymatic Browning Criteria to Sea Buckthorn Juice during Thermal Processing. *Journal of Food Process Engineering, 38*(1), 67-75.

Yang, B., Halttunen, T., Raimo, O., Price, K., & Kallio, H. (2009). Flavonol glycosides in wild and cultivated berries of three major subspecies of *Hippophaë rhamnoides* and changes during harvesting period. *Food Chemistry, 115*(2), 657-664.

Yang, B. R., & Kallio, H. P. (2001). Fatty acid composition of lipids in sea buckthorn (*Hippophae rhamnoides* L.) berries of different origins. *Journal of Agricultural and Food Chemistry, 49*(4), 1939-1947.

Yang, M., Yang, D., & Yu, X. (2018). Soil microbial communities and enzyme activities in sea-buckthorn (*Hippophae rhamnoides*) plantation at different ages. *PLOS ONE, 13*(1), e0190959.

Zhang, J., Zhou, H.-C., He, S.-B., Zhang, X.-F., Ling, Y.-H., Li, X.-Y., Zhang, H., & Hou, D.-D. (2021). The immunoenhancement effects of sea buckthorn pulp oil in cyclophosphamide-induced immunosuppressed mice. *Food & Function, 12*(17), 7954-7963.

Zhao, Z., Shahrour, I., Bai, Z., Fan, W., Feng, L., & Li, H. (2013). Soils development in opencast coal mine spoils reclaimed for 1–13 years in the West-Northern Loess Plateau of China. *European Journal of Soil Biology, 55*, 40-46.

Zheng, H. X., Mao, L. K., Yang, J. Y., Zhang, C. Y., Miao, S., & Gao, Y. X. (2020). Effect of Oil Content and Emulsifier Type on the Properties and Antioxidant Activity of Sea Buckthorn Oil-in-Water Emulsions. *Journal of Food Quality, 2020*.

Zheng, J.-S., Sharp, S. J., Imamura, F., Chowdhury, R., Gundersen, T. E., Steur, M., Sluijs, I., van der Schouw, Y. T., Agudo, A., & Aune, D. (2020). Association of plasma biomarkers of fruit and vegetable intake with incident type 2 diabetes: EPIC-InterAct case-cohort study in eight European countries. *bmj, 370*.

Zhou, X., Tian, L., Zhang, J., Ma, L., Li, X., & Tian, C. (2017). Rhizospheric fungi and their link with the nitrogen-fixing Frankia harbored in host plant Hippophae rhamnoides L. *Journal of Basic Microbiology, 57*(12), 1055-1064.