Effect of Sea Buckthorn Biomass on Oxidation Stability and Sensory Attractiveness of Cereal Biscuits

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The purpose of this work was to investigate the effect of 5%, 10%, 15%, and 20% additions of sea buckthorn biomass to cereal biscuits and analyze the oxidation stability and sensory attractiveness. The oxidation stability of the biscuits was evaluated with an Oxitest reactor under 6.0 bar oxygen pressure at 110 °C, and the increase in the induction period with increasing addition of sea buckthorn biomass up to 15% level was found. An increase in the induction period was observed with increasing addition of sea buckthorn biomass up to 15% level. In contrast, 20% addition of biomass caused a decrease in the induction period by 30 h compared to the induction period with 15% biomass addition. Sensory analysis revealed that brittleness and hardness of the biscuits decreased with increasing addition of sea buckthorn biomass. Overall, the most sensory acceptable from the point of view of assessors were biscuits with 15% addition. It was concluded that 15% addition of sea buckthorn biomass to cereal biscuits was the most optimal content in terms of oxidation stability and sensory attractiveness. The results of this study pointed out the excellent possibilities of fortification of cereal products with sea buckthorn biomass.

Keywords: Sea buckthorn; Biomass; Cereal biscuits; Oxidation stability; Sensory analysis; Food fortification

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INTRODUCTION

Sea buckthorn (SB) (*Hippophae rhamnoides* L.) is an exceptionally valuable plant with juicy, soft, and yellow-orange succulent berries and is wildly distributed in Asia, Europe, and Canada (Teleszko *et al.* 2015; Zielińska and Nowak 2017; Ciesarová *et al.* 2020). Its popularity is still growing, mainly due to its berries, leaves, and bark, which are abundant in many bioactive substances (Suryakumar and Gupta 2011). The SB berries are rich in carbohydrates, fat-soluble vitamins, antioxidants, essential fatty acids, amino acids, phytosterols, and flavonoids (Beveridge *et al.* 1999). Lipophilic antioxidants (primarily carotenoids and tocopherols) and hydrophilic antioxidants (flavonoids, tannins, phenolic acids, and ascorbic acid) are present in eminently high quantities, which contributes to an exceptional value (Ciesarová *et al.* 2020). Flavonoids can dominate mainly in leaves, while phenolic compounds are concentrated in the pulp and peel of berries or seeds (Saikia 2013; Fatima *et al.* 2015). Whole berries are suggested for nutrition as a part of food products or in their natural form due to their valuable biochemical composition (Bal *et al.* 2011).

Concerning utilization in the food industry, the SB is used mainly for formulation of products such as juices and oils (Zeb 2004; Cenkowski *et al.* 2006; Lipowski *et al.* 2009). The application of SB berries for juice extraction leads to the formation of residues in large amount. The pomaces consisting of pulp, seed, and skin create 20% of total fruit weight (Rösch *et al.* 2004; Dulf *et al.* 2012; Radenkovs *et al.* 2018). The SB by-products are commonly utilized as animal feed or for extraction of biologically active compounds in order to minimize waste production. (Périno-Issartier *et al.* 2011). Another possibility of application is the addition of SB by-products to bakery products in order to increase their nutritional value (Lougas *et al.* 2005; Kant *et al.* 2012). The studies realized by Stoin *et al.* (2014), Muresan *et al.* (2019), and Guo *et al.* (2019) confirmed the possibility of using SB by-products in development of bakery products with antioxidant properties. Therefore, the present study is focused on the application of SB biomass in cereal biscuits and its effect on the oxidation stability and sensory attractiveness of the biscuits produced.

EXPERIMENTAL

Sea Buckthorn Biomass

Sea buckthorn (*Hippophae rhamnoides* L.) of cultivar 'Leikora' was grown in Tvrdošovce (Agricultural farm, Slovakia). The biomass was obtained as a waste by-product after pressing the whole berries. Subsequently, it was dried, ground, and sieved into flour with particle sizes of 40 to 75 μm.

Cereal Biscuits Preparation

Cereal biscuits were prepared according to the modified recipe of Tyagi *et al.* (2007) three times. The cookies contained 0%, 5%, 10%, 15%, and 20% additions of SB biomass as a replacement of wheat flour. They were prepared using the following basic formula: wheat flour special 00 (100.0 g), sugar powder (53.0 g), butter containing 82% fat (36.5 g), baking soda (1.1 g), edible salt (0.9 g), and water (12.0 mL). The raw materials were mixed to obtain the dough, which was rolled to a thickness of approximately 3 mm. The cookies were baked in conventional electric oven at 180 °C for 8 min. Cereal biscuit without the addition of biomass flour was served as a control.

Determination of Fat Content and Dry Matter

The fat content was determined following the ISO 659 (2009) method. The dry matter analysis was performed according to Príbela (1993). All analyses were performed in triplicate.

Determination of Oxidation Stability of Biscuits

Oxitest (VELP Scientifica Srl, Usmate Velate, Italy) was used to determine the oxidation stability of the biscuits. The analysis was performed in triplicate, at 110 °C and under an over-pressure 6 bar of pure oxygen. Approximately 5.0 to 10.0 g of samples were used for each determination.

Texture Analysis

Parameters, such as brittleness and hardness, were determined in all prepared samples using a texture analyser TA.XT Plus (Stable Micro Systems, Ltd., Godalming, UK) with a 3-point bending rig probe (part code HDP/3PB) and a platform (HDP/90)

(Stable Micro Systems, Ltd., Godalming, UK). The measure- force in compression mode was used, with an initial velocity of 1.0 mm/s. The test speed was set at 1.0 mm/s, and the speed after testing was 10.0 mm/s. The arm spacing was set to 3 mm.

Sensory Analysis

All samples of biscuits with various contents of SB biomass were used for sensory evaluation. The SB biomass powder was used as a standard. It was attended by 6 assessors, 4 women and 2 men, aged 25 to 70 years, who noted their answers in the prescribed forms. The pleasant taste of the biscuits was rated on a line-marking scale of 1.0 to 10, where 1 was a 'very unpleasant', 5 was 'neutral', and 10 was a 'very pleasant' taste. The intensity of the descriptor such as aroma, structural properties, overall acceptability was evaluated to the same extent, where 10 was noted as 'high intensity'.

Statistical Analysis

All analyses were performed in triplicate, and differences were considered significant at ($p < 0.05$) in different samples. Mean values of experimental data were determined with confidence interval (95%), calculated with single-variable analysis of data.

RESULTS AND DISCUSSION

The total fat content in biscuits was determined with 10% addition of SB biomass as 16.7%, while Muresan *et al.* (2019) reported 30.11% to 30.48% in the same addition level. This difference may be attributed to the much higher thermal treatment. Because the seeds and fruits are rich in fatty substances and acids, biscuits containing the by-product of SB processing have a much higher fat content than that of other types of biscuits.

As the values of individual types of biscuits did not show a noticeable increase and but indicated a decreasing tendency, the average value of moisture (dry matter) could be stated as 5.23%. This relatively low value of moisture content indicated that biscuits are a low-moisture food, as the dry matter content did not exceed 25% (Knechtges 2012).

The most acceptable value of the induction period was determined in biscuits with 15% addition of SB biomass (Fig. 1). It was supposed that this was due to the presence of antioxidants in SB biomass. Muresan *et al.* (2019) determined the DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) antioxidant activity of biscuits with 10% addition of SB powder as 88.97% (with thermal treatment 50 °C, 12 h) to 89.14% (with thermal treatment 80 °C, 5 h).

It was found that the induction period increased with a 15% addition of SB biomass compared to the control sample. This may be due to the presence of polyphenols, which are considered to be the most active compounds responsible for the antioxidant properties of Hippophae species (Ji *et al*. 2020). According to Gao *et al.* (2000), the antioxidant capacity of SB berries is ascribed to combined action of ascorbic acid, polyphenols (phenolic acid and flavonoids), and carotenoids. Remarkably, a noticeable decrease was observed during the induction period at 20% addition (Fig. 1). Sotler *et al.* (2019) report that some antioxidants may act as prooxidants at higher concentrations. Thus, it may be the cause of this decline. Structure of polyphenols as *ortho*-di/trihydroxylated compounds is more capable of prooxidant activity than their mono-hydroxylated polyphenolic analogs (Cheng and Breen 2000).

The results in Table 1 show that with increasing addition of SB biomass, the hardness of biscuits was decreased. This may be due to a gradual reduction in the gluten content of the biscuits, which has slowed down the formation of gluten matrices, as well as the competition of sugar and flour for water (Chauhan *et al.* 2016; Giri and Sakhale 2019).

Table 1. Sensory Parameters of Biscuits

Type of Biscuits/ Parameters	0%	5%	10%	15%	20%
Hardness (kg)	6.00 ± 0.38[a]	4.36 ± 0.30[a]	3.75 ± 0.31[a]	3.55 ± 0.04 [a]	0.79 ± 0.03 [a]
Brittleness (cm)	3.77 ± 0.06[b]	3.76 ± 0.02[b]	3.72 ± 0.07[b]	3.69 ± 0.06[b]	3.59 ± 0.02[b]

Note: The statistical criteria were applied and value behind ± indicate confidence interval,
The small letters a–b within a row with superscripts differ significantly ($p < 0.05$).

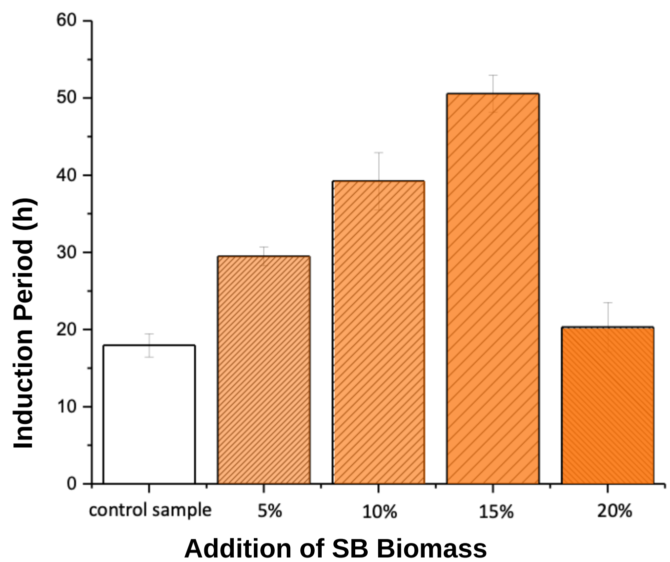
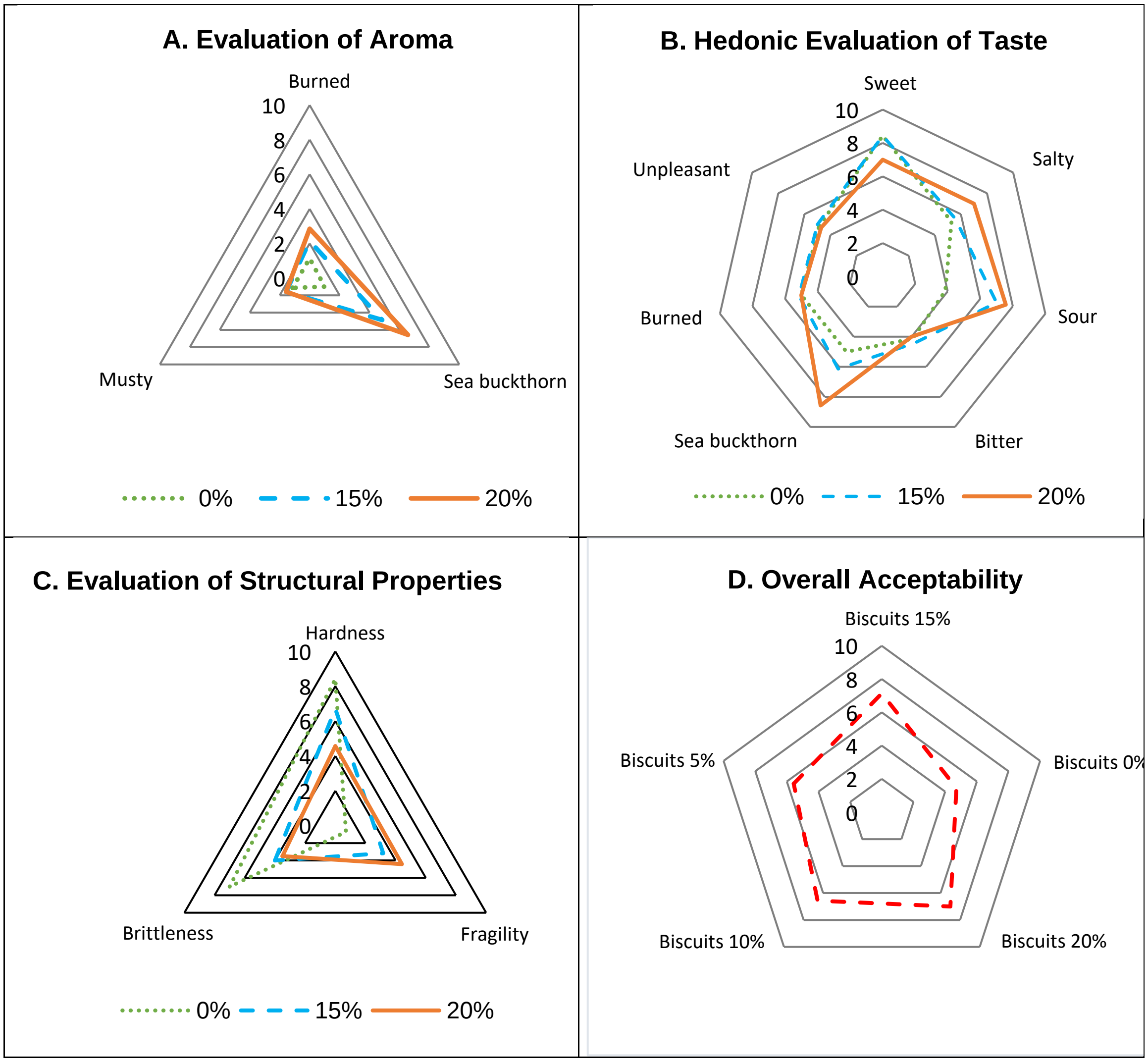


Fig. 1. Effect of 5%, 10%, 15%, and 20% additions of SB biomass on oxidation stability of cereal biscuits

According to Su *et al.* (2019), organic acids, such as malic acid, fumaric acid, or citric acid, also gave bakery products with a decreased hardness. The limited activity of amylases in the dough, as well as the content of phenolic compounds, could also contribute to these decreasing hardness values (Mildner-Szkudlarz *et al.* 2013; Kuchtová *et al.* 2018). The hardest biscuit sample contained no SB biomass. Kuchtová *et al.* (2018) reported the same observations for biscuits with different contents of skins and grape seeds. According to Assis *et al.* (2009), texture analysis parameters, such as brittleness and hardness, are desirable to be as low as possible. They play an important role in the evaluation of bakery products, because of their close connection with consumers' perception of freshness.

As shown in Fig. 2, the encouraging result was that with the increasing addition of SB biomass, the intensity of SB aroma was also increased with no increase in unwanted odor. Musty odor was not present at all, as well as no burned odor detected.



Note: 5% and 10% additions of SB biomass did not have a noticeable effect on sensory parameters, so they were not reported.

Fig. 2. Summary of sensory evaluation

The evaluators considered SB taste to be the most pleasant, followed by sweet and sour. The biscuits with a 20% addition had the most pleasant acidity and SB taste. The acidity of the biscuits was increased with the addition of SB biomass because of the presence of organic acids and sugars in it (Ciesarová *et al.* 2020).

Biscuits with no SB biomass added were designated as the hardest and at the same time the most fragile. In contrast, biscuits with 20% SB addition were considered hard and brittle at the minimum. From sensory results, it was concluded that with increasing addition of SB biomass, a notable decrease in biscuits hardness was achieved. In contrast, Stoin *et al.* (2014) noted that digestive cookies with 10% SB additions were crispy in comparison with hard and brittle control sample.

Regarding the overall acceptability shown in Fig. 2, the assessors did not evaluate any sample with different addition of SB by more than 7 points from the maximum 10 possible points. The biscuits with 15% addition of SB biomass were the most pleasant in total, and *vice versa* the most unpleasant biscuits were those without any SB addition. In contrast, Muresan *et al.* (2019) found that biscuits with 10% SB addition obtained maximum score in 9-point hedonic scale. According to Stoin *et al.* (2014), it could be observed that the digestive cookies with 10% SB addition showed higher values (up to 19.71 points from the maximum 20 possible points) towards control sample (17.85 points).

CONCLUSIONS

1. The 15% addition of sea buckthorn (SB) biomass exhibited the best effect on oxidation stability. Overall, 15% and 20% addition were the most sensory attractive to consumers.
2. The interesting finding was that at 20% addition of SB biomass a noticeable decrease in the induction period of 30 h was recorded. This could be attributed to some antioxidants from SB biomass probably acting as prooxidants. Phenolic antioxidants can act as prooxidants in SB biomass. Small polyphenols that are simply oxidized, such as gallic acid and quercetin, can exhibit prooxidant activity. However, large molecular-weight phenolic compounds, such as hydrolysable and condensed tannins, have a little or no prooxidant properties (Eghbaliferiz and Iranshahi 2016).
3. In contrast, the sensory evaluation revealed a positive effect of addition of SB in biscuits: with increased addition of SB, the intensity of SB aroma increased without unwanted odor, the most pleasant SB taste, appropriate acidity, and a remarkable decrease in hardness.
4. With this work, it was pointed out that even by-products of processing, such as SB biomass, can be further used in food and thus improve their stability and organoleptic properties.

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REFERENCES CITED

Assis, L., Zavareze, E. D. R., Radünz, A. L., Dias, Á., Gutkoski, L. C., and Elias, M. C. (2009). "Propriedades nutricionais, tecnológicas e sensoriais de biscoitos com substituição de farinha de trigo por farinha de aveia ou farinha de arroz parboilizado [Nutritional, technological and sensory properties of biscuits with substitution of wheat flour for oat flour or parboiled rice flour]," *Alimentos e Nutrição Araraquara* 20, 15-24.

Bal, L. M., Meda, V., Naik, S., and Satya, S. (2011). "Sea buckthorn berries: A potential source of valuable nutrients for nutraceuticals and cosmeceuticals," *Food Research International* 44(7), 1718-1727. DOI: 10.1016/j.foodres.2011.03.002

Beveridge, T., Li, T. S., Oomah, B. D., and Smith, A. (1999). "Sea buckthorn products: Manufacture and composition," *Journal of Agricultural and Food Chemistry* 47(9), 3480–3488. DOI: 10.1021/jf981331m

Cenkowski, S., Yakimishen, R., Przybylski, R., and Muir, W. (2006). "Quality of extracted sea buckthorn seed and pulp oil," *Canadian Biosystems Engineering* 48, 9-16.

Chauhan, A., Saxena, D., and Singh, S. (2016). "Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies," *Cogent Food & Agriculture* 2(1), Article ID 1125773. DOI: 10.1080/23311932.2015.1125773

Cheng, I. F., and Breen, K. (2000). "On the ability of four flavonoids, baicilein, luteolin, naringenin, and quercetin, to suppress the Fenton reaction of the iron-ATP complex," *Biometals* 13(1), 77-83. DOI: 10.1023/A:1009229429250

Ciesarová, Z., Murkovic, M., Cejpek, K., Kreps, F., Tobolková, B., Koplík, R., Belajová, E., Kukurová, K., Daško, Ľ., and Panovská, Z. (2020). "Why is sea buckthorn (*Hippophae rhamnoides* L.) so exceptional? A review," *Food Research International* 133, Article ID 109170. DOI: 10.1016/j.foodres.2020.109170

Dulf, F. V., Andrei, S., Bunea, A., and Socaciu, C. (2012). "Fatty acid and phytosterol contents of some Romanian wild and cultivated berry pomaces," *Chemical Papers* 66(10), 925-934. DOI: 10.2478/s11696-012-0156-0

Eghbaliferiz, S., and Iranshahi, M. (2016). "Prooxidant activity of polyphenols, flavonoids, anthocyanins and carotenoids: Updated review of mechanisms and catalyzing metals," *Phytotherapy Research* 30, 1379-1391. DOI: 10.1002/ptr.5643

Fatima, T., Kesari, V., Watt, I., Wishart, D., Todd, J. F., Schroeder, W. R., Paliyath, G., and Krishna, P. (2015). "Metabolite profiling and expression analysis of flavonoid, vitamin C and tocopherol biosynthesis genes in the antioxidant-rich sea buckthorn (*Hippophae rhamnoides* L.)," *Phytochemistry* 118, 181-191. DOI: 10.1016/j.phytochem.2015.08.008

Gao, X., Ohlander, M., Jeppsson, N., Björk, L., and Trajkovski, V. (2000). "Changes in antioxidant effects and their relationship to phytonutrients in fruits of sea buckthorn (*Hippophae rhamnoides* L.) during maturation," *Journal of Agricultural and Food Chemistry* 48(5), 1485-1490. DOI: 10.1021/jf991072g

Giri, N. A., and Sakhale, B. (2019). "Development of sweet potato flour based high protein and low calorie gluten free cookies," *Current Research in Nutrition and Food Science Journal* 7(2), 427-435. DOI: 10.12944/CRNFSJ.7.2.12

Guo, X., Shi, L., Yang, S., Yang, R., Dai, X., Zhang, T., Liu, R., Chang, M., Jin, Q., and Wang, X. (2019). "Effect of sea-buckthorn pulp and flaxseed residues on quality and shelf life of bread," *Food & Function* 10(7), 4220-4230. DOI: 10.1039/C8FO02511H

ISO 659 (2009). "Oilseeds – Determination of oil content (Reference method)," International Organization for Standardization, Geneva, Switzerland.

Ji, M., Gong, X., Li, X., Wang, C., and Li, M. (2020). "Advanced research on the antioxidant activity and mechanism of polyphenols from *Hippophae* species – A review," *Molecules* 25(4), Article Number 917. DOI: 10.3390/molecules25040917

Kant, V., Mehta, M., and Varshneya, C. (2012). "Antioxidant potential and total phenolic contents of sea buckthorn (*Hippophae rhamnoides*) pomace," *Free Radicals and Antioxidants* 2(4), 79-86. DOI: 10.5530/ax.2012.4.14

Knechtges, P. L. (2012). “Food safety: Engineering controls and technology,” in: *Food Safety: Theory and Practice*, P. L. Knechtges (ed.), Jones and Bartlett Learning, Burlington, MA, USA, pp. 219-266.
Kuchtová, V., Kohajdová, Z., Karovičová, J., and Lauková, M. (2018). “Physical, textural and sensory properties of cookies incorporated with grape skin and seed preparations,” *Polish Journal of Food and Nutrition Sciences* 68(4), 309-317. DOI: 10.2478/pjfns-2018-0004
Lipowski, J., Marszałek, K., and Skąpska, S. (2009). “Sea buckthorn – An innovative raw material for the fruit and vegetable processing industry,” *Journal of Fruit and Ornamental Plant Research* 17(2), 121-126.
Lougas, T., Veskus, T., Martverk, K., Täht, R., Rada, K., and Vokk, R. (2005). “Sea buckthorn and its new field use,” in: *IntraFood – EFFOST Conference*, Valencia, Spain, pp. 719-722.
Mildner-Szkudlarz, S., Bajerska, J., Zawirska-Wojtasiak, R., and Górecka, D. (2013). “White grape pomace as a source of dietary fibre and polyphenols and its effect on physical and nutraceutical characteristics of wheat biscuits,” *Journal of the Science of Food and Agriculture* 93(2), 389-395. DOI: 10.1002/jsfa.577
Mureșan, E. A., Chiș, S., Cerbu, C. G., Man, S., Pop, A., Marc, R., Mureșan, V., and Muste, S. (2019). “Development and characterization of biscuits based on sea buckthorn and blueberries by-products,” *Journal of Agroalimentary Processes and Technologies* 25(2), 59-63.
Périno-Issartier, S., Abert-Vian, M., and Chemat, F. (2011). “Solvent free microwave-assisted extraction of antioxidants from sea buckthorn (*Hippophae rhamnoides*) food by-products,” *Food and Bioprocess Technology* 4(6), 1020-1028. DOI: 10.1007/s11947-010-0438-x
Príbela, A. (1993). *Analýza Potravín: Cvičenie [Food Analysis: Practice]*, Slovak University of Technology, Bratislava, Slovakia.
Radenkovs, V., Püssa, T., Juhnevica-Radenkova, K., Anton, D., and Seglina, D. (2018). “Phytochemical characterization and antimicrobial evaluation of young leaf/shoot and press cake extracts from *Hippophae rhamnoides* L.,” *Food Bioscience* 24, 56-66. DOI: 10.1016/j.fbio.2018.05.010
Rösch, D., Krumbein, A., and Kroh, L. W. (2004). “Antioxidant gallocatechins, dimeric and trimeric proanthocyanidins from sea buckthorn (*Hippophae rhamnoides*) pomace,” *European Food Research and Technology* 219(6), 605-613. DOI: 10.1007/s00217-004-1002-6
Saikia, M. (2013). “Antioxidant and antibacterial activity of leaf, bark, pulp and seed extracts of sea buckthorn (*Hippophae salicifolia* D. Don) of Sikkim Himalayas,” *Journal of Medicinal Plants Research* 7(19), 1330-1338. DOI: 10.5897/JMPR12.1123
Sotler, R., Poljšak, B., Dahmane, R., Jukić, T., Jukić, D. P., Rotim, C., Trebše, P., and Starc, A. (2019). “Prooxidant activities of antioxidants and their impact on health,” *Acta Clinica Croatica* 58(4), 726-736. DOI: 10.20471/acc.2019.58.04.20
Stoin, D., Dogaru, D. V., Poiana, M. A., Bordean, D., and Cocan, I. (2014). “Use of sea buckthorn bioactive potential in obtaining of farinaceous functional products,” *Journal of Agroalimentary Processes and Technologies* 20(4), 396-403.
Su, X., Wu, F., Zhang, Y., Yang, N., Chen, F., Jin, Z., and Xu, X. (2019). “Effect of organic acids on bread quality improvement,” *Food Chemistry* 278, 267-275. DOI: 10.1016/j.foodchem.2018.11.011

Suryakumar, G., and Gupta, A. (2011). "Medicinal and therapeutic potential of Sea buckthorn (*Hippophae rhamnoides* L.)," *Journal of Ethnopharmacology* 138(2), 268-278. DOI: 10.1016/j.jep.2011.09.024

Teleszko, M., Wojdyło, A., Rudzińska, M., Oszmiański, J., and Golis, T. (2015). "Analysis of lipophilic and hydrophilic bioactive compounds content in sea buckthorn (*Hippophae rhamnoides* L.) berries," *Journal of Agricultural and Food Chemistry* 63(16), 4120–4129. DOI: 10.1021/acs.jafc.5b00564

Tyagi, S., Manikantan, M., Oberoi, H. S., and Kaur, G. (2007). "Effect of mustard flour incorporation on nutritional, textural and organoleptic characteristics of biscuits," *Journal of Food Engineering* 80(4), 1043-1050. DOI: 10.1016/j.jfoodeng.2006.08.016

Zeb, A. (2004). "Chemical and nutritional constituents of sea buckthorn juice," *Pakistan Journal of Nutrition* 3(2), 99-106. DOI: 10.3923/pjn.2004.99.106

Zielińska, A., and Nowak, I. (2017). "Abundance of active ingredients in sea-buckthorn oil," *Lipids in Health and Disease* 16(1), Article Number 95. DOI: 10.1186/s12944-017-0469-7

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