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Unveiling the Health Benefits of Polyunsaturated Fatty Acids in Medicinal Plants

Shahryar Shakeri*

Department of Biotechnology, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran

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Abstract

This review explores the therapeutic potential of polyunsaturated fatty acids (PUFAs) derived from medicinal plants. PUFAs, including omega-3 and omega-6 fatty acids, play critical roles in human health and are essential for various physiological functions. While marine sources are known for their high content of omega-3 PUFAs, medicinal plants also serve as valuable sources of omega-6 important fatty acids. PUFAs derived from medicinal plants exhibit a wide range of therapeutic properties, including anti-inflammatory, antioxidant, neuroprotective, cardiovascular protective, and anticancer effects. This review summarizes the classification and sources of PUFAs, and discusses the extraction of PUFAs from medicinal plants. Specific medicinal plants rich in PUFAs are highlighted, along with their potential health benefits. Understanding the role of PUFAs in promoting human well-being opens avenues for the development of natural interventions and therapeutic approaches. By exploring the rich composition of PUFAs in medicinal plants, we can harness their potential in preventive healthcare and complement existing treatments. Overall, this review provides valuable insights into the medicinal properties of PUFAs derived from plants.

1. Introduction

In recent years, there has been growing interest in exploring the PUFAs present in medicinal plants due to their potential health benefits (Rizzo et al., 2023). This review aims to summarize the current knowledge regarding the presence, distribution, and therapeutic potential of polyunsaturated fatty acids (PUFAs) in various medicinal plants. PUFAs are a category of fatty acids that play critical roles in human health and are essential for various physiological functions (Kapoor et al., 2021). These fatty acids possess multiple double bonds in their carbon chain, which differentiates them from saturated and monounsaturated fatty acids. PUFAs can further be classified into omega-3 (n-3) and omega-6 (n-6) fatty acids based on the location of the first double bond counting from the methyl (omega) end of the hydrocarbon chain (Calder & Yaqoob, 2009). PUFAs are not synthesized by the human body

* Corresponding author: Department of Biotechnology, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran
Email: sh.shakeri@kgut.ac.ir

and must be obtained from dietary sources. While marine sources, such as fish and algae, are well-known for their high content of omega-3 PUFAs, medicinal plants also serve as valuable sources of these important fatty acids. Omega-6 polyunsaturated fatty acids (PUFAs) are a type of essential fatty acids that play a crucial role in maintaining overall health and well-being. While omega-6 PUFAs such as dihomo-γ-linolenic acid (DGLA), alpha-linoleic acid (LA) and arachidonic acid (AA), typically associated with sources like vegetable oils and seeds, several medicinal plants also contain significant amounts of these beneficial fatty acids (Simopoulos, 2002). Omega-3 PUFAs, including α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA), have garnered significant attention due to their potential health-promoting properties. These fatty acids are known for their involvement in crucial physiological processes, including cellular signaling, anti-inflammatory responses, brain function, and cardiovascular health (Mozaffarian & Wu, 2011). In contrast, omega-6 PUFAs, such as LA and AA are also essential for maintaining proper bodily functions, playing key roles in hormone synthesis, immunity, and cell membrane integrity. Medicinal plants have been recognized throughout various traditional medicinal systems for their therapeutic properties, and recent scientific studies have begun to unravel the mechanisms behind these effects (Nyakudya et al., 2020). It has become evident that PUFAs derived from medicinal plants contribute significantly to the health benefits, making them a topic of increasing interest within the field of medicinal plants (Freije et al., 2013). In this review paper, we aim to explore the therapeutic potential of PUFAs derived from medicinal plants, focusing on their anti-inflammatory, antioxidant, neuroprotective, cardiovascular protective, and anticancer properties. We will discuss specific medicinal plants that are rich in PUFAs and have been extensively studied for their impact on human health. Understanding the role of PUFAs in promoting human well-being is of great significance, as it opens avenues for the development of natural interventions and therapeutic approaches. By exploring the rich composition of PUFAs in medicinal plants, we can further harness their potential in preventive healthcare and complement existing treatments. Therefore, this review aims to provide valuable insights into the health benefits of PUFAs derived from medicinal plants.

2.Classification and Sources of PUFAs:

Polyunsaturated fatty acids (PUFAs) can be classified into omega-3 (ALA, EPA and DHA) and omega-6 (LA, DGLA, ARA) categories. Omega-3 PUFAs, found abundantly in fish oil, algae, flaxseed, and chia seeds, are known for their anti-inflammatory properties and potential cardiovascular benefits. Omega-6 PUFAs are commonly found in vegetable oils, such as soybean oil and sunflower oil, and play crucial roles in cell signaling and immune function. For instance, the seeds of the evening primrose plant (*Oenothera biennis*) are a notable source of omega-6 fatty acids, particularly GLA. GLA has anti-inflammatory properties and may aid in managing conditions like rheumatoid arthritis and eczema (Calder, 2010; Majdinasab et al., 2018). Also, Borage (*Borago officinalis*) is an herb known for its edible leaves and beautiful blue star-shaped flowers. It contains significant amounts of GLA, making it beneficial for skin health and reducing inflammation (Naghdi Badi et al., 2007; Montaner et al., 2021). Black currant (*Ribes nigrum*) seed oil is a popular supplement due to its high content of omega-6 GLA. It has been studied for its potential role in supporting heart health and reducing vascular inflammation (Bakowska-Barczak et al., 2009; Piskernik et al., 2018). ALA can be found in Hemp (*Cannabis sativa*) seeds and hemp oil. They are excellent sources of omega-6 PUFAs, specifically ALA. ALA can be converted by the body into other

omega-6 fatty acids as needed. Hemp also provides a balanced ratio of omega-3 to omega-6 fatty acids (Petrovic et al., 2015)

3.Extraction and Analysis of PUFAs from Medicinal Plants:

Various extraction methods such as solvent extraction and super critical fluid Extraction are used to separate the polyunsaturated fatty acids (PUFAs) from medicinal plants (Ferdosh et al., 2022). Also, gas chromatography (GC) (Osw et al., 2017), high-performance liquid Chromatography (HPLC) and mass spectrometry (MS) are commonly used techniques for analysis of PUFAs (Freije et al., 2013; Daga et al., 2021). Solvent extraction involves using a solvent to dissolve the PUFAs from the plant material. One popular method is soxhlet extraction, which uses a continuous cycle of solvent evaporation and condensation to extract the PUFAs. The supercritical fluid extraction involves using supercritical fluids, typically carbon dioxide, as the solvent. Under specific conditions of temperature and pressure, carbon dioxide becomes a supercritical fluid with properties of both a liquid and a gas. This technique is valued for its ability to extract high-quality PUFAs without leaving behind any solvent residues (Devi et al., 2019). Once the PUFAs are extracted, they can be quantified and identified using various analytical techniques. GC is a common method for analyzing fatty acid composition. It involves vaporizing the PUFAs and separating them based on their volatility in a gas chromatograph, providing precise quantitative data on the different fatty acids present (Chiu et al., 2020). Also, HPLC is another technique used to separate and quantify different compounds, including PUFAs. It employs a liquid mobile phase and a stationary phase to separate the PUFAs based on their chemical and physical properties (Carvalho et al., 2012). Moreover, GC-MS is a powerful analytical technique that enables the identification and quantification of PUFAs based on their molecular masses. Mass spectrometers ionize the PUFAs and separate them based on their mass-to-charge ratios, providing detailed information about their structures (Saini et al., 2014).

4. Therapeutic Potential of PUFAs in Medicinal Plants:

PUFAs derived from medicinal plants exhibit a wide range of therapeutic properties, making them of great interest in the field of natural medicine. Some key therapeutic activities associated with these compounds include:

4-1. Anti-inflammatory activity:

PUFAs, particularly omega-3 fatty acids, have shown promising anti-inflammatory effects by modulating inflammatory pathways and reducing the production of pro-inflammatory molecules (Shahrajabian & Sun, 2023). Medicinal plants rich in omega-3 fatty acids, such as flaxseed (*Linum usitatissimum*), purslane (*Portulaca oleracea*), and black currant (*Ribes nigrum*) (Savikin et al., 2013; Lee & Lee, 2019), have been studied for their potential anti-inflammatory benefits. Inflammation is a complex physiological response generated by the immune system to protect the body against infection, injury, or harmful stimuli (Gonzalez-Castejon et al., 2012). However, chronic inflammation can lead to various diseases, including cardiovascular disorders, autoimmune conditions, and neurodegenerative disorders. PUFAs derived from medicinal plants have been found to exhibit potent anti-inflammatory properties, offering a natural approach to modulate inflammation and potentially prevent or treat related diseases (Tabart et al., 2012). The anti-inflammatory activity of PUFAs is primarily attributed to their conversion into specialized pro-resolving mediators (SPMs) (Calder, 2010). SPMs, such as resolvins, protectins, and maresins, are derived from omega-3 PUFAs and are involved in actively resolving inflammation and promoting

tissue repair. These SPMs exert their effects by regulating various cellular processes, including immune cell recruitment, cytokine production, and oxidative stress (Serhan, 2005). Omega-3 PUFAs, such as EPA and DHA, have been extensively studied for their anti-inflammatory effects. These fatty acids inhibit the synthesis of pro-inflammatory molecules, such as prostaglandins, leukotrienes, and cytokines, by competing with omega-6 fatty acids, such as arachidonic acid (AA), for enzymatic conversion pathways. By reducing the production of these pro-inflammatory mediators, omega-3 PUFAs help to dampen the inflammatory response (Recchiuti & Serhan, 2012). Medicinal plants rich in omega-3 PUFAs, such as flaxseed, chia seeds (seeds of *Salvia hispanica*), and hemp seeds (seeds of *Cannabis sativa*), have been investigated for their anti-inflammatory potential. For example, flaxseed, which contains a high amount of alpha-linolenic acid (ALA), the precursor of EPA and DHA, has been shown to reduce inflammation markers in various studies (Bassett et al., 2009; Rahimlou et al., 2019; Li et al., 2023). Similarly, chia seeds, renowned for their omega-3 content, exhibit anti-inflammatory effects by modulating inflammatory markers and reducing the activity of inflammatory enzymes (Nieman et al., 2009). In addition to omega-3 PUFAs, omega-6 PUFAs, such as gamma-linolenic acid (GLA) found in medicinal plants like evening primrose oil (Timoszuk et al., 2018) and borage oil (De Haro et al., 2002), also play a role in inflammation modulation (Barre, 2009). GLA is converted into dihomo-gamma-linolenic acid (DGLA), which competes with AA for enzymatic conversion. By increasing the proportion of DGLA, the synthesis of pro-inflammatory eicosanoids derived from AA is reduced, thus exerting anti-inflammatory effects. Furthermore, PUFAs have been shown to impact immune cell function. PUFAs can modulate the activity of immune cells, such as macrophages, lymphocytes, and dendritic cells, by altering their phenotype and function. This modulation leads to a shift towards an anti-inflammatory profile, resulting in reduced inflammation within the body. PUFAs also suppress the activation of nuclear factor-kappa B (NF-κB), a key regulatory protein involved in the transcription of pro-inflammatory genes (Calder, 2017).

4-2. Antioxidant potential of PUFAs in medicinal plants:

PUFAs serve as important antioxidants, protecting the body against oxidative stress and free radical damage. Medicinal plants such as sea buckthorn (*Hippophae rhamnoides*) and grape seed (*Vitis vinifera*) contain PUFAs with potent antioxidant properties, contributing to their therapeutic effects in various conditions (Fatima et al., 2012; Luntraru et al., 2022). They act by reducing oxidative stress and inflammation by neutralizing free radicals and preventing cellular damage. Polyunsaturated fatty acids found abundantly in grape seed oil are potent antioxidants. They can scavenge free radicals and reduce inflammation in the body, providing protective effects against chronic diseases like cardiovascular conditions, neurodegenerative disorders, and certain cancers (Garavaglia et al., 2016). Several medicinal plants such as chia seeds oil contain PUFAs with significant antioxidant potential. Incorporating PUFAs from medicinal plants into a balanced diet can contribute to the body's antioxidant defenses and help reduce oxidative stress, inflammation, and the risk of chronic diseases (Sargi et al., 2013). Evening Primrose (*Oenothera biennis*) seeds contain high levels of GLA, an omega-6 fatty acid with antioxidant and anti-inflammatory properties. It has been used in traditional medicine to alleviate symptoms of inflammation-related conditions like eczema and rheumatoid arthritis (Farag et al., 2023). Black Currant (*Ribes nigrum*) seed oil is rich in omega-3 and omega-6 fatty acids, including ALA and GLA. These fatty acids contribute to its antioxidant and anti-

inflammatory effects, making it beneficial for cardiovascular health and inflammatory conditions (Oczkowski, 2021). Hemp (*Cannabis sativa*) seeds and oil are a valuable source of omega-3 and omega-6 fatty acids. These PUFAs contribute to its antioxidant properties, supporting overall health and wellness (Rupasinghe et al., 2020).

4-3. Neuroprotective effects:

Many medicinal plants rich in PUFAs also possess significant antioxidant properties (Miquel, 2008). Antioxidants help protect the brain against oxidative stress, a process that can lead to neuronal damage. By neutralizing harmful free radicals, medicinal plants containing PUFAs can reduce oxidative damage and preserve the integrity of brain cells. Chronic inflammation in the brain can contribute to neurodegenerative diseases. PUFAs found in medicinal plants possess anti-inflammatory properties, which help reduce inflammatory responses in the brain. By modulating inflammation, these PUFAs can protect neurons from damage and support overall brain health (Wang et al., 2016). PUFAs are crucial components of cell membranes in the brain and play a vital role in neuronal signaling. They facilitate efficient communication between neurons, thereby supporting optimal brain function. This enhanced signaling aids in cognitive processes like learning, memory, and overall brain performance (Navaie et al., 2018).

4-4. Cardiovascular protection:

PUFAs found in certain medicinal plants have been associated with cardiovascular protection and maintaining heart health (Recchiuti & Serhan, 2012). Some medicinal plants rich in omega-6 PUFAs include evening primrose oil, borage oil, and flaxseed oil. Omega-6 PUFAs contribute to cardiovascular protection by reducing LDL cholesterol levels (the "bad" cholesterol) and improving blood vessel function (Jiang et al., 2022). PUFAs found in medicinal plants also exhibit antioxidant and anti-inflammatory properties. By neutralizing free radicals and reducing inflammation, they protect the cardiovascular system from oxidative stress and inflammation-induced damage. These actions contribute to the maintenance of healthy blood vessels and the prevention of cardiovascular diseases (Alipoor et al., 2012).

4-5. Anticancer properties:

Some medicinal plants containing PUFAs have demonstrated anticancer properties, inhibiting tumor growth and promoting apoptosis in cancer cells (Arumugam & Ramesh, 2011). Examples include evening primrose (*Oenothera biennis*) (Timoszuk et al., 2018) and borage (*Borago officinalis*) (Montaner et al., 2021), which are rich in GLA, an omega-6 PUFA. Omega-6 PUFAs, such as LA, can also play a role in cancer prevention and treatment when balanced with omega-3 PUFAs. Some studies suggest that specific omega-6 fatty acids, such as GLA, found in these plants, may have anticancer effects. However, the overall impact of omega-6 PUFAs on cancer is complex, as excessive consumption of certain omega-6 fatty acids may promote inflammation and tumor progression. Chronic inflammation and oxidative stress are closely linked to cancer development. PUFAs possess anti-inflammatory and antioxidant properties, which can help counteract these processes. By reducing inflammation and neutralizing free radicals, PUFAs contribute to creating an unfavorable environment for tumor growth and progression (Arsic et al., 2023).

4-6. Cosmetic applications:

The incorporation of PUFAs in cosmetics offers invaluable benefits in maintaining and enhancing the health and appearance of the skin and hair (Moore et al., 2020). PUFAs, particularly omega-3 and omega-6, possess remarkable moisturizing, anti-inflammatory, and regenerative properties (Bialek et al., 2016). PUFAs help to maintain skin

barrier integrity, enhance hydration, and reduce transepidermal water loss when incorporated into cosmetic formulations such as creams, lotions, and serums (Manosroi et al., 2019). Moreover, they contribute to soothing and calming irritated or inflamed skin, making them suitable for sensitive or acne-prone skin types. PUFAs also aid in improving skin elasticity and texture by promoting collagen synthesis and reducing the appearance of fine lines and wrinkles (Yao et al., 2021). Additionally, PUFAs nourish and moisturize the hair, impart shine, and enhance manageability, when used in hair care products (Zanzottera et al., 2017).

5.Conclusion:

PUFAs present in medicinal plants offer a vast array of potential therapeutic applications. These natural sources of PUFAs have been studied for their anti-inflammatory, antioxidant, neuroprotective, cardiovascular protective and anticancer properties. Extracting and analyzing PUFAs from medicinal plants through various methods provide a rich pool of potential therapeutic compounds. Continued research in this field may unlock further insights into the mechanisms of action and optimize extraction techniques, ultimately paving the way for the development of novel preventive and therapeutic interventions in modern medicine. This review highlights the significance of PUFAs in medicinal plants and their potential therapeutic applications. The diverse range of medicinal plants serving as natural sources of PUFAs offers promising opportunities for the development of novel preventive and therapeutic for various diseases. Further research is warranted to explore the mechanisms of action of PUFAs from these medicinal plants, ultimately enhancing their potential in modern medicine.

6.References

1.Rizzo G, Baroni L, Lombardo M. Promising sources of plant-derived polyunsaturated fatty acids: A narrative review. International Journal of Environmental Research and Public Health. 2023;20(3):1683.

2.Kapoor B, Kapoor D, Gautam S, Singh R, Bhardwaj S. Dietary polyunsaturated fatty acids (PUFAs): Uses and potential health benefits. Current Nutrition Reports. 2021;10:232-42.

3.Calder PC, Yaqoob P. Understanding omega-3 polyunsaturated fatty acids. Postgraduate medicine. 2009;121(6):148-57.

4.Simopoulos AP. Omega-3 fatty acids in inflammation and autoimmune diseases. Journal of the American College of nutrition. 2002;21(6):495-505.

5.Mozaffarian D, Wu JHY. Omega-3 fatty acids and cardiovascular disease: effects on risk factors, molecular pathways, and clinical events. Journal of the American College of Cardiology. 2011;58(20):2047-67.

6.Nyakudya TT, Tshabalala T, Dangarembizi R, Erlwanger KH, Ndhlala AR. The potential therapeutic value of medicinal plants in the management of metabolic disorders. Molecules. 2020;25(11):2669.

7.Freije A, Alkhuzai J, Al-Laith AA. Fatty acid composition of three medicinal plants from Bahrain: New potential sources of Î³-linolenic acid and dihomo-Î³-linolenic. Industrial Crops and Products. 2013;43:218-24.

8.Calder PC. Omega-3 fatty acids and inflammatory processes. Nutrients. 2010;2(3):355-74.

9.Majdinasab N, Namjoyan F, Taghizadeh M, Saki H. The effect of evening primrose oil on fatigue and quality of life in patients with multiple sclerosis. Neuropsychiatric disease and treatment. 2018:1505-12.

10.Montaner C, Zufiaurre R, Movila M, Mallor C. Evaluation of borage (*Borago officinalis* L.) genotypes for nutraceutical value based on leaves fatty acids composition. Foods. 2021;11(1):16.

11.Naghdi Badi H, Soroshzadeh A, Rezazadeh S, Sharifi M, Ghalavand A, Omidi H. Review on borage (valuable medicinal plant and the richest

plant source of gamma linolenic acid). Journal of Medicinal Plants. 2007;6(24):1-16.
12.Bakowska-Barczak AM, Schieber A, Kolodziejczyk P. Characterization of Canadian black currant (*Ribes nigrum* L.) seed oils and residues. Journal of agricultural and food chemistry. 2009;57(24):11528-36.
13.Piskernik Sa, Vidrih R, Demsar L, Koron D, Rogelj M, Zontar TP. Fatty acid profiles of seeds from different Ribes species. LWT. 2018;98:424-7.
14.Petrovic M, Debeljak Z, Kezic N, Dzidara P. Relationship between cannabinoids content and composition of fatty acids in hempseed oils. Food Chemistry. 2015;170:218-25.
15.Ferdosh S, Yunus K, Rashid MA, Sarker ZI. Extraction and characterization of fatty acids from the leaves and stems of *Clinacanthus nutans* using supercritical carbon dioxide and soxhlet method. The Natural Products Journal. 2022;12(6):49-55.
16.Osw P, Hs Hussain F, Gozzini D, Vidari G. GC-MS determination and identification of eleven fatty acids in triglycerides isolated from the seeds of traditional kurdish medicinal plant *Anchusa azurea*. Eurasian Journal of Science and Engineering. 2017;3(2):230-40.
17.Daga P, Vaishnav SR, Dalmia A, Tumaney AW. Extraction, fatty acid profile, phytochemical composition and antioxidant activities of fixed oils from spices belonging to Apiaceae and Lamiaceae family. Journal of Food Science and Technology. 2021:1-14.
18.Devi V, Khanam S. Study of w-6 linoleic and w-3 a-linolenic acids of hemp (*Cannabis sativa*) seed oil extracted by supercritical CO2 extraction: CCD optimization. Journal of Environmental Chemical Engineering. 2019;7(1):102818.
19.Chiu H-H, Kuo C-H. Gas chromatography-mass spectrometry-based analytical strategies for fatty acid analysis in biological samples. Journal of food and drug analysis. 2020;28(1):60-73.
20.Carvalho MS, Mendonca MrA, Pinho DMM, Resck IS, Suarez PAZ. Chromatographic analyses of fatty acid methyl esters by HPLC-UV and GC-FID. Journal of the Brazilian Chemical Society. 2012;23:763-9.
21.Saini RK, Shetty NP, Giridhar P. GC-FID/MS analysis of fatty acids in Indian cultivars of Moringa oleifera: potential sources of PUFA. Journal of the American Oil Chemists' Society. 2014;91(6):1029-34.
22.Shahrajabian MH, Sun W. Survey on medicinal plants and herbs in traditional Iranian medicine with anti-oxidant, anti-viral, anti-microbial, and anti-inflammation properties. Letters in Drug Design & Discovery. 2023;20(11):1707-43.
23.Savikin KP, Dordevic BS, Ristic MS, Krivokuca D, Pljevljakusic DS, Vulic T. Variation in the fatty-acid content in seeds of various black, red, and white currant varieties. Chemistry & Biodiversity. 2013;10(1):157-65.
24.Lee Y, Lee J-Y. Blackcurrant (*Ribes nigrum*) extract exerts an anti-inflammatory action by modulating macrophage phenotypes. Nutrients. 2019;11(5):975.
25.Gonzalez-Castejon M, Visioli F, Rodriguez-Casado A. Diverse biological activities of dandelion. Nutrition reviews. 2012;70(9):534-47.
26.Tabart J, Franck T, Kevers C, Pincemail Jl, Serteyn D, Defraigne J-O, et al. Antioxidant and anti-inflammatory activities of Ribes nigrum extracts. Food Chemistry. 2012;131(4):1116-22.
27.Serhan CN. Novel w 3-derived local mediators in anti-inflammation and resolution. Pharmacology & therapeutics. 2005;105(1):7-21.
28.Recchiuti A, Serhan CN. Pro-resolving lipid mediators (SPMs) and their actions in regulating miRNA in novel resolution circuits in inflammation. Frontiers in immunology. 2012;3:298.
29.Rahimlou M, Jahromi NB, Hasanyani N, Ahmadi AR. Effects of flaxseed interventions on circulating inflammatory biomarkers: a systematic review and meta-analysis of

randomized controlled trials. Advances in Nutrition. 2019;10(6):1108-19.
30.Li J, Chen J, Huang P, Cai Z, Zhang N, Wang Y, et al. The Anti-Inflammatory Mechanism of Flaxseed Linusorbs on Lipopolysaccharide-Induced RAW 264.7 Macrophages by Modulating TLR4/NF-ÎºB/MAPK Pathway. Foods. 2023;12(12):2398.
31.Bassett CMC, Rodriguez-Leyva D, Pierce GN. Experimental and clinical research findings on the cardiovascular benefits of consuming flaxseed. Applied physiology, nutrition, and metabolism. 2009;34(5):965-74.
32.Nieman DC, Cayea EJ, Austin MD, Henson DA, McAnulty SR, Jin F. Chia seed does not promote weight loss or alter disease risk factors in overweight adults. Nutrition Research. 2009;29(6):414-8.
33.Timoszuk M, Bielawska K, Skrzydlewska Eb. Evening primrose (*Oenothera biennis*) biological activity dependent on chemical composition. Antioxidants. 2018;7(8):108.
34.De Haro A, Dominguez V, del Rio M. Variability in the content of gamma-linolenic acid and other fatty acids of the seed oil of germplasm of wild and cultivated borage (*Borago officinalis* L.). Journal of Herbs, Spices & Medicinal Plants. 2002;9(4):297-304.
35.Barre DE. Borage, evening primrose, blackcurrant, and fungal oils; Î³-linolenic acid-rich oils. Gourmet and health-promoting specialty oils: Elsevier; 2009. p. 237-66.
36.Calder PC. Omega-3 fatty acids and inflammatory processes: from molecules to man. Biochemical Society Transactions. 2017;45(5):1105-15.
37.Luntraru CM, Apostol L, Oprea OB, Neagu M, Popescu AF, Tomescu JA, et al. Reclaim and Valorization of Sea Buckthorn (*Hippophae rhamnoides*) By-Product: Antioxidant Activity and Chemical Characterization. Foods. 2022;11(3):462.
38.Fatima T, Snyder CL, Schroeder WR, Cram D, Datla R, Wishart D, et al. Fatty acid composition of developing sea buckthorn (*Hippophae rhamnoides* L.) berry and the transcriptome of the mature seed. PloS one. 2012;7(4):e34099.
39.Garavaglia J, Markoski MM, Oliveira A, Marcadenti A. Grape seed oil compounds: Biological and chemical actions for health. Nutrition and metabolic insights. 2016;9:NMI. S32910.
40.Sargi SCi, Silva BC, Santos HMC, Montanher PF, Boeing JS, Santos JÃºnior OO, et al. Antioxidant capacity and chemical composition in seeds rich in omega-3: chia, flax, and perilla. Food Science and Technology. 2013;33:541-8.
41.Farag M, Reda A, Nabil M, Elimam D, Zayed A. Evening primrose oil: A comprehensive review of its bio-actives, extraction, analysis, oil quality, therapeutic merits, and safety. Food & Function. 2023.
42.Oczkowski M. Health-promoting effects of bioactive compounds in blackcurrant (*Ribes nigrum* L.) Berries. Roczniki PaÅ„stwowego ZakÅ‚adu Higieny. 2021;72(3):229-38.
43.Rupasinghe HPV, Davis A, Kumar SK, Murray B, Zheljazkov VD. Industrial hemp (*Cannabis sativa* subsp. sativa) as an emerging source for value-added functional food ingredients and nutraceuticals. Molecules. 2020;25(18):4078.
44.Miquel MIR. Echium oil: A valuable source of n-3 and n-6 fatty acids. OlÃ©agineux, Corps gras, Lipides. 2008;15(4):252-6.
45.Wang J, Song Y, Gao M, Bai X, Chen Z. Neuroprotective effect of several phytochemicals and its potential application in the prevention of neurodegenerative diseases. Geriatrics. 2016;1(4):29.
46.Navaie F, Hassanzadeh G, Mahakizadeh S, Mehrannia K, Alizamir T, Dashti N, et al. Anti-oxidative and neuroprotective effects of supplementary flaxseed on oxidative damage in the hippocampus area of a rat model of hypoxia. Archives of Neuroscience. 2018;5(4).

47.Jiang W, Liang J, Xiong M, Dong Y. Efficacy of flaxseed oil compared with fish oil supplementation in the treatment of coronary heart disease: a retrospective study. Journal of Thoracic Disease. 2022;14(2):396.
48.Alipoor B, Haghighian MK, Sadat BE, Asghari M. Effect of sesame seed on lipid profile and redox status in hyperlipidemic patients. International Journal of Food Sciences and Nutrition. 2012;63(6):674-8.
49.Arumugam P, Ramesh S. Protective effects of sesame oil on 4-NQO-induced oxidative DNA damage and lipid peroxidation in rats. Drug and Chemical Toxicology. 2011;34(2):116-9.
50.Arsic A, Krstic P, Paunovic M, Nedovic J, Jakovljevic V, Vucic V. Anti-inflammatory effect of combining fish oil and evening primrose oil supplementation on breast cancer patients undergoing chemotherapy: a randomized placebo-controlled trial. Scientific Reports. 2023;13(1):6449.
51.Moore EM, Wagner C, Komarnytsky S. The enigma of bioactivity and toxicity of botanical oils for skin care. Frontiers in pharmacology. 2020;11:785.
52.Bialek A, Bialek M, Jelinska M, Tokarz A. Fatty acid profile of new promising unconventional plant oils for cosmetic use. International journal of cosmetic science. 2016;38(4):382-8.
53.Manosroi A, Chankhampan C, Kietthanakorn BO, Ruksiriwanich W, Chaikul P, Boonpisuttinant K, et al. Pharmaceutical and cosmeceutical biological activities of hemp (*Cannabis sativa* L. var. sativa) leaf and seed extracts. Chiang Mai Journal of Science. 2019;46:180-95.
54.Yao Q, Jia T, Qiao W, Gu H, Kaku K. Unsaturated fatty acid-enriched extract from *Hippophae rhamnoides* seed reduces skin dryness through up-regulating aquaporins 3 and hyaluronan synthetases 2 expressions. Journal of Cosmetic Dermatology. 2021;20(1):321-9.
55.Zanzottera F, Bizzaro G, Michelotti A, Nobile V. Efficacy of a nutritional supplement, standardized in fatty acids and phytosterols, on hair loss and hair health in both women and men. Journal of Cosmetology and Trichology. 2017;3(121):2.