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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Evaluation of Fatty Acid Profile and Fatty Acid-Related Nutritional Quality Indices of Zebra Mussel (*Dreissena polymorpha*)

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Abstract: Essential omega-3 polyunsaturated fatty acids (n-3 PUFAs) are vital to human health and prevent a range of ailments; mussels are a good source of these PUFAs. The objective of this study was to evaluate the potential of zebra mussel (*Dressiana polymorpha*) as a functional food by measuring the fatty acid composition and nutritional quality parameters. Lipid amount, fatty acid composition and nutritional quality indices was determined in the oil of zebra mussel with solvent extraction and the potential of zebra mussel as nutraceutical and pharmaceutical was evaluated. Although its low lipid content zebra mussel displayed FA profiles that were beneficial to human health. Major fatty acid group in the zebra mussel was SFAs and it was followed by MUFA and PUFA groups. Sum of EPA and DHA amounts were 14.05±1.36. Besides, n-6/n-3 ratio of zebra mussel was 0.09. PUFA/SFA ratio of zebra mussel was 0.36. AI, TI and HH values were 0.60, 0.45 and 1.09, respectively. The current study indicated the lipid quality and beneficial fatty acids of zebra mussels for evaluation as functional dietary components.

Keywords: Zebra mussel, fatty acid profile, nutritional quality indices, nutraceutical, pharmaceutical.

Zebra Midyesinin (*Dreissena polymorpha*) Yağ Asidi Profili Ve Yağ Asidine Bağlı Besinsel Kalite Indekslerinin Değerlendirilmesi

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Öz: Esansiyel omega-3 çoklu doymamış yağ asitleri (n-3 PUFA'lar) insan sağlığı için hayati öneme sahiptir ve bir dizi rahatsızlığı önler; midyeler bu PUFA'ların iyi bir kaynağıdır. Bu çalışmanın amacı, yağ asidi bileşimini ve besin kalitesi parametrelerini ölçerek zebra midyesinin (Dressiana polymorpha) fonksiyonel bir gıda olarak potansiyelini değerlendirmektir. Zebra midyesi yağında çözücü ekstraksiyonla lipid miktarı, yağ asidi bileşimi ve besin kalitesi endeksleri belirlendi ve zebra midyesinin nutrasötik ve farmasötik olarak potansiyeli değerlendirildi. Zebra midyesi düşük lipid içeriğine rağmen insan sağlığına faydalı olan yağ asidi profilleri gösterdi. Zebra midyesindeki majör yağ asidi grubu SFA'lar olup bunu MUFA ve PUFA grupları izledi. EPA ve DHA miktarlarının toplamı 14,05±1,36 olarak bulundu. Ayrıca zebra midyesinin n-6/n-3 oranı 0,09 olarak bulundu. Zebra midyesinin PUFA/SFA oranı 0,36 olarak bulundu. AI, TI ve HH değerleri sırasıyla 0,60, 0,37 ve 1,09'du. Mevcut çalışma, zebra midyelerinin lipid kalitesini ve yararlı yağ asitlerini işlevsel diyet bileşenleri olarak değerlendirmeye işaret etmektedir.

Anahtar kelimeler: Zebra midye, yağ asidi profili, besin kalitesi endeksleri, nutrasötik, farmasötik.

INTRODUCTION

Marine habitats provide a wealth of nutrient-rich food that is essential to human health and wellness. Many governments and dietary standards encourage increasing the consumption of seafood since it offers a variety of essential nutrients that are typically lacking in daily diets (Biandolini et al., 2023). The evolution of marine organisms and their specific physiological and biochemical adaptations has led to a rich molecular diversity of chemical compounds, which provides a promising opportunity for the discovery of novel bioactive compounds with novel structures and novel biological activities (Zhukova, 2014). The class Bivalvia is extensively studied within the phylum Mollusca, and it holds significant importance for numerous reasons. In addition to being commercially valuable as a food for humans and for feeding certain marine crustaceans, the biological and pharmacological applications of the polyunsaturated fatty acids (PUFA) found in these mollusks are of significant interest. Mussels are rich in omega-6 and omega-3 fatty acids, as well as saturated, monounsaturated, and other polyunsaturated fatty acids. These qualities make mussels a low-fat diet with significant bioactive capabilities (Moniruzzaman et al., 2021). The distribution of freshwater bivalves is very diverse worldwide. Because of their biological filtration function, these mussels are extremely valuable to the freshwater ecology. They serve as a trophic bridge connecting higher trophic species with primary production (Keskinbalta & Çelik, 2020).

Numerous chemical researchers have experimented with marine mollusks in an effort to isolate and identify novel natural compounds (Zhukova, 2014). So that, it is feasible to use some unusual sources of minerals, proteins, lipids, and carbohydrates to create foods with high nutritional value (Ullah et al., 2021). One of these, the freshwater zebra mussel (*Dreissena polymorpha*), has significant nutrients (protein, fat, and minerals (Nalepa et al., 1993), but it is just unutilized to create foods with nutritional value. Besides, the zebra mussel, through its excessive growth, obstructs the channels in dam lakes, restricting water flow. Furthermore, this species lacks any economic benefit.

Consumers, who are becoming more concerned with adopting a healthier diet, have taken a keen interest in food products' fatty acid (FA) profiles. FAs are among the most significant natural, physiologically active substances. EPA and DHA, two types of n-3 PUFAs, are essential for numerous metabolic and physiological processes and can be found in virtually every cell membrane (Biandolini et al., 2023). Clinical and epidemiological research has eventually found a correlation between meat and fish oil consumption and a reduced risk of cardiovascular disease. The heart responds strongly to eicosapentaenoic (EPA) and docosahexaenoic (DHA) fatty acids' significant antiarrhythmic and antithrombotic effects. Under typical circumstances, the maintenance of cell membranes, brain functions, and nerve impulse transmission require linoleic (AA) and linolenic (ALA) acids (Cavali et al., 2022). FAs can be helpful or harmful in diagnosing, treating, and preventing disease. For instance, PUFAs may positively affect MS patients while SFAs may increase the likelihood of acquiring multiple sclerosis (MS) and the course of the disease. Another illustration is that some key FA metabolites may have beneficial effects on health, such as neuroprotection and anti-inflammation, but they may also have detrimental effects, such as inflammation, necrosis promoters, and atherosclerosis. FAs are often derived via a variety of dietary sources, which have a particular FA composition and subsequently affect health outcomes. In this light, it is important to evaluate the FA composition to establish its nutritional and/or therapeutic significance, particularly in fatty-acid-rich foods, dietary supplements, and herbal remedies (Chen & Liu, 2020).

Lipid damage, caused by the hydrolysis and oxidation of the lipid portion, is one of several processes that can cause fish to degrade while being stored on ice. This can result in significant nutritional value and quality losses during chilled storage. The health lipid indices of atherogenicity (AI, demonstrating the inhibition of the aggregation of plaque and lowering the levels of esterified FA, cholesterol, and phospholipids, thereby preventing the emergence of micro- and macro-coronary diseases) and thrombogenicity (TI, demonstrating the propensity to form clots in the blood vessels) are proposed to assess the nutritional quality of lipids in fish Simat et al., 2015).

Therefore, the aim of this study was to determine the potential of Zebra mussel (*Dressiana polymorpha*) as a nutraceutical and pharmaceutical ingredient by evaluating fatty acid profile and nutritional quality indices.

MATERIAL AND METHOD

Raw material: Zebra mussels (*D. polymorpha)* were obtained from the Keban Dam Lake. They were placed in ventilated plastic containers in ice and immediately transported to the laboratory. Whole bodies of zebra mussels were dissected, and lipid extraction was performed.

Lipid extraction: Lipid extraction from zebra mussels was performed according to the method of (Bligh & Dyer, 1959). The lipid in the sample is extracted by a polar solvent mixture of chloroform, and methanol (2:1), which gives a one-phase system. The sample was weighed, and a chloroform: methanol mixture was added. Thereafter, $CaCl_3$ was added to the chloroform: methanol mixture and left in the dark overnight. The chloroform:

methanol phase was separated from the $CaCl_3$ phase the day after. The chloroform: methanol was evaporated in a rotary evaporator (R210, Buchi). Then the sample is put into an oven to remove moisture. The fat content is determined in an aliquot of the chloroform phase by weighing the lipids after evaporation of the solvent and removing moisture. The method will extract both neutral and polar lipids.

Fatty acid composition: COI/T.20/Doc. No 33 method was used for the determination of fatty acid methyl esters (FAME) (OIC, 2017). A 37-component mixture of FAME (Supelco) has been chosen as the standard for retention time to identify the fatty acids. The area ratio, which is under the relevant peak, was used for the quantitative analysis. An Agilent 6890 GC-FID system was used for FAME analysis. The column was an Agilent HP-88 capillary column (100 m x 0.25 mm ID x 0.2 µm). The split ratio was 1:100 injection and detector temperatures were 250°C and 260°C, respectively. The temperature program was as follows; the oven temperature is held at 120°C for 1 min and then increased to 240°C at a rate of 4°C min^{-1} and hold for 5 min.

Nutritional quality indices: In accordance with WHO guidelines, fatty acid profile data were combined to determine the ratio of ΣPUFAs / ΣSFAs and the ratio of ΣPUFAs (n-6/n-3) (Cavali et al., (2022). Ulbricht and Southgate (1991) also determined the atherogenic (AI) and thrombogenic (TI) indices, indicating that foods that are favorable for cardiovascular health had lower values. AI is a crucial determinant of the quality of the oils that can fend off cardiovascular diseases. The TI shows that blood clots have formed in the vessel. Prothrombogenic (saturated) fatty acids and anti-thrombogenic fatty acids (MUFA, omega-6 PUFA, and omega-3 PUFA) are defined by TI, and the ratio of omega-3 to omega-6 PUFA is regarded as a key indicator of oil quality (Roy et al., 2022). Both indices examine the relationship between unsaturated (UFA) and saturated (SFA) fatty acids. UFA are the opposite of SFA, which is typically pro-thrombogenic (a greater propensity to form clots in blood vessels) and pro-atherogenic (favors lipids' adhesion to cells) (Fonseca et al., 2022). The impact of meal fatty acid composition on cholesterol is evaluated using the hypocholesterolemic/hypercholesterolemic (H/H) index (Santo et al., 2002).

$$\mathrm{AI}=\frac{(\mathrm{C12{:}0}+4\times\mathrm{C14{:}0}+\mathrm{C16{:}0})}{(\Sigma\mathrm{MUFA}+\Sigma(\text{n-6})+\Sigma(\text{ n-3})}$$

$$\mathrm{TI}=\frac{(\mathrm{C14{:}0}+\mathrm{C16{:}0}+\mathrm{C18})}{[(0.5\ \mathrm{x}\ \Sigma\mathrm{MUFA}+0.5\ \mathrm{x}\ (\text{n-6})+3\ \mathrm{x}\ (\text{n-3})+(\text{n-3})/(\text{n-6})]}$$

$$\mathrm{HH}=\frac{[(C18{:}1n-9+C18{:}2n-6+C20{:}4n-6+C18{:}3n-3+C20{:}5n-3+C22{:}6n-3)}{(C14{:}0+C16{:}0)]}$$

Statistical analysis: The data expressed as mean values ± standard deviation. The oil extraction experiments were performed in triplicate (n = 3). For each triplicate, at least three measurements were performed. Fatty acid composition was performed in triplicate (n = 3).

RESULTS

Fatty acid profile: Fatty acid (FA) composition of zebra mussel oil (ZMO) is presented in Figure 1. Level of total lipid (TL) in ZMO was 0.9±0.04% wet weight (w/w) and total of 19 fatty acids were identified in ZMO. The determined saturated fatty acids in zebra mussels are pentadecanoic acid (15:0), palmitic acid (16:0), margaric acid (17:0), stearic acid (18:0), arachidic acid (20:0), behenic acid (22:0), and lignoceric acid (24: 0). The recognized cis-fatty acids are palmitoleic acid (16:1 n-7), oleic acid (18:1 n-9), gondoic acid (20: 1 n-9), and linoleic acid (18: 2 n-6). The three known omega-3 fatty acids are alfa-linolenic acid (18: 3 n-3), eicosapentaenoic acid (20: 5 n-3), and docosahexaenoic acid (22: 6 n-3). The recognized omega-6 fatty acids are docosadienoic acid (22:2 n-6), eicosadienoic acid (20:2 n-6), and linoleic acid (18:2 n-6). Nervonic acid (24:1 n-9) is the identified omega-9 fatty acid.

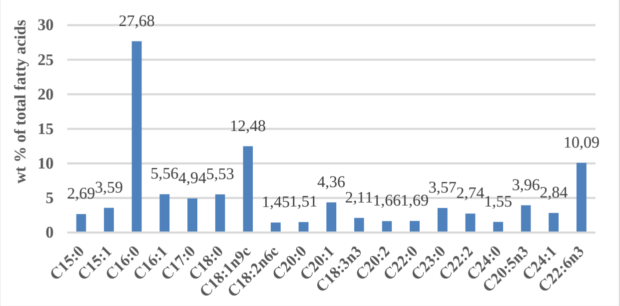

Figure 1. Most abundant fatty acids in zebra mussel (*Dreissena polymorpha*)

The detected saturated fatty acids in zebra mussel are pentadecanoic acid (15: 0), palmitic acid (16: 0), margaric acid (17:0), stearic acid (18:0), arachidic acid (20: 0), behenic acid (22: 0), and lignoceric acid (24: 0). The recognized cis-fatty acids are palmitoleic acid (16:1 n-7), oleic acid (18:1 n-9), gondoic acid (20: 1 n-9), and linoleic acid (18: 2 n-6). The three known omega-3 fatty acids are alfa-linolenic acid (18: 3 n-3), eicosapentaenoic acid (20: 5 n-3), and docosahexaenoic acid (22: 6 n-3). The recognized omega-6 fatty acids are docosadienoic acid (22:2 n-6), eicosadienoic acid (20:2 n-6), and linoleic acid (18:2 n-6). Nervonic acid (24:1 n-9) is the identified omega-9 fatty acid.

The major fatty acids in the SFA group were palmitic acid (C16:0), followed by heptadecanoic (C17:0) and stearic acid (C18:0). Palmitic acid constituted about approximately 27% of the total SFAs. Stearic acid was another frequently found fatty acid in mussels and together, they constitute 2/3 of the total SFAs. Zebra mussel included a higher proportion of SFA compared to MUFA. The major group in the MUFAs were oleic (C18:1n9c) and followed by palmitoleic acid (16:1 n-7) and gondoic acid (20: 1 n-9). Oleic acid (C18:1n9c) constituted approximately half of the total MUFAs and oleic (C18:1n9c) and palmitoleic acid (16:1 n-7) together, constituted more than half of the total MUFAs. The predominant fatty acids in the PUFA groups were docosahexaenoic acid (DHA) (C22:6n3), followed by eicosapentaenoic (EPA) (C20:5 n3). DHA constituted approximately 60 % of total PUFAs. The FA distribution of ZMO follows the order: Saturated fatty acids (SFAs) (49.16 % of total fatty acids) > Monounsaturated fatty acids (MUFAs) (28.83 %) > Polyunsaturated fatty acids (PUFAs) (17.61%).

Nutritional quality indices:Using nutritional indicators based on fatty acid composition, the nutritional lipid quality of ZMO was assessed. Nutritional quality profiles of ZMO were presented in Figure 2. The PUFA/SFA, n-6/n-3, EPA+DHA were assessed. PUFA/SFA ratio of ZMO was 0.36 which was slightly below the recommended limits. The quantities of n-3 PUFA were greater than those of n-6 PUFA. n6/n3 ratio of ZMO was 0.09 which was a good provider of DHA and EPA among the n3 series. Lower AI and TI were produced by the ZMO, which had a low n-6/n-3 ratio due to a higher n-3 content. Sum of EPA and DHA amounts were 14.05±1.36 and extremely lower than the recommended limits. AI and TI of ZMO were found 0.6 and 0.45, respectively. AI and TI indices show that ZMO can contribute to human health. H/H index of zebra mussel was 1.09.

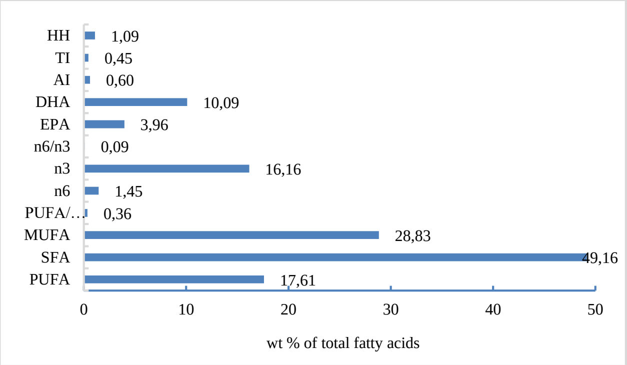

Figure 2. Nutrition quality indices of lipids in zebra mussel (*Dreissena polymorpha*)

DISCUSSION

The abundance of advantageous macro and micronutrients that are vital for human health, especially the high concentration of good fatty acids, make seafood a highly valued food source (Fonseca et al., 2022). Numerous biotic and abiotic elements, including food availability, UV radiation, water temperature, salinity, UV radiation and an abundance of food, affect the lipid content of marine species (Cherifi et al., 2018; Panayotova et al., 2021; Peycheva et al., 2021). Therefore, the investigation of the fatty acid profile of aquatic animals is important for the evaluation of health benefits. Similar results to TL content of ZMO have found from different researchers (Biandolini et al., 2023; Cherifi et al., 2018; Haldar et al., 2014; Keskinbalta & Çelik, 2020). From a nutritional perspective, the ZMO can be classified as a lean species, with a lipid content of less than 2%, and a low-fat species, with a lipid level ranging from 2% to 4%. The low lipid content of ZMO, which is consistent with other studies of *Mytilus galloprovincialis* that have been published by the Panayotova et al., (2021). Peycheva et al., (2021) have reported that TL content of wild and farmed *Mytilus galloprovincialis* were respectiveliy ranged between 2.27-2.35 and 1.37-1.31.

Although its low lipid content, ZMO displayed FA profiles that were beneficial to human health. Order of FA groups of ZMO was similar to the mussel species reported by Prato et al. (2020). Fatty acids belong to SFAs and MUFAs were similar reported by Şereflişan and Altun Ersoy (2018) which have also been reported that palmitic acid was the major FA and, it was followed by stearic acid in *Anodonta pseudodopsis* and *Unio tigridis*, however major MUFA was oleic acid in *A. pseudodopsis* whereas it was palmitoleic acid representing one third of MUFAs in *U. tigridis*. Similar to this study, Peycheva et al. (2021) reported that the major SFAs in *Mytilus galloprovincialis* were palmitic acid (C16:0) and stearic acid (C18:0), and SFAs were higher than MUFAs. EPA and DHA were the major PUFAs in this study. Accordingly, Cherifi et al. (2018) have been reported DHA and EPA were the most important PUFAs in their *Mytilus galloprovincialis* samples. Prato et al. (2020) have reported that DHA and EPA were the predominant unsaturated FAs in bivalves. Marine bivalves have a restricted capacity to produce PUFAs from scratch and instead rely on obtaining them from the available food sources in their environment. Due to the inability of mussels to produce LC-PUFAs, it is necessary to acquire DHA through dietary sources. The increased levels of DHA could be attributed to the abundance of zooplankton and dinoflagellates in the mussels' food sources (Peycheva et al., 2021).

Nutritional parameters were taken into consideration to determine the dietary quality of lipids and the potential effects on human health. Functional foods that provide health benefits beyond nutrition and reduce the risk of chronic disease are increasingly regarded (Prato et al., 2020). The health advantages associated with consuming bivalves can be evaluated by analyzing nutritional quality indices, including the PUFA/SFA n-6/n-3, AI, TI, and HH indices and the levels of EPA + DHA (in mg/100 g of edible portion)

The PUFA/SFA ratio is a commonly employed measure for assessing the influence of food on cardiovascular health and oxidative stress (Biandolini et al. 2023). The optimum range for PUFA/SFA ratio of *Mytilus galloprovincialis* is 0.45-4.00 (Peycheva et al. 2021). Prato et al. (2020) reported that all species from the Ionian Sea showed the PUFA/SAFA ratio >0.45. Peycheva et al., (2021) found that PUFA/SFA were between 0.69-3.08 in *Mytilus galloprovincialis* and Panayotova et. al., (2021) reported that PUFA/SFA were between 0.65-3.07 in *Mytilus galloprovincialis*. Nevertheless, certain studies deem PUFA/SFA as feeble and insufficient when it comes to serving as a reliable measure of the nutritional worth of fats, citing various reasons. The total amount of polyunsaturated fatty acids (PUFA) does not differentiate between the types n-3 and n-6. Consequently, having a high proportion of PUFA is not automatically beneficial if it is not properly balanced in terms of the ratio between n-6 and n-3 PUFA (Biandolini et al. 2023).

The n-6/n-3 ratio is a dependable indication for evaluating the relative nutritional value of oil obtained from aquatic organisms. Both n-3 and n-6-series PUFAs serve as precursors to eicosanoids, which play a role in regulating inflammation through contrasting mechanisms. n-6 derivatives stimulate inflammation, platelet aggregation, and vasoconstriction, leading to a pro-inflammatory response. On the other hand, n-3 derivatives suppress inflammation and platelet aggregation, and promote vasodilation, resulting in an anti-inflammatory and resolving response. For optimal health, the UK Department of Health recommends maintaining a maximum n-6/n-3 ratio of 4.0. Enhancing the ratio is vital for diminishing the occurrence of coronary heart illnesses, plasma cholesterol levels, and cancer risks. Hence, it is imperative to uphold an equitable proportion of these two PUFA categories in our dietary intake to ensure optimal human development, overall health, and the prevention of contemporary chronic ailments (Biandolini et al., 2023). In the present study, n-6/n-3 was consistent with the previous studies. Şereflişan and Ersoy Altun (2018) have reported that the n6/n3 ratio of *A. pseudodopsis* and *U. tigridis* was 0.90 and 0.99, respectively. Prato et al., (2020) reported that very favourable ratios n-6/n-3 well below the recommended values were observed, with values within the range of 0.1-1.0. Moniruzzaman et al., (2021) found n-6/n-3 was ranged from 0.2 (*C. virginica*) to 3.69 (*P. globosa*). Marine bivalves typically contain a significant amount of n-3 PUFAs and have a low n-6/n-3 ratio. As a result, they are regarded as a reliable and environmentally friendly source of n-3 PUFAs for human diet.

The total amount of EPA and DHA (mg 100 g^{-1} ; w w^{-1}) is a crucial indicator of the nutritional value of lipids, offering significant insights on the quantity and quality of marine animal products (Biandolini et al., 2023). The species can be categorized as a "good source" of fatty acids (FAs) based on its DHA and EPA concentration (Panayotova et al., 2021). The content of eicosapentaenoic acid plus docosahexaenoic acid (EPA+DHA) was ascertained in accordance with the guidelines provided by the European Food Safety Authority about the dietary reference values for lipid (EFSA, 2010). WHO (2010) recommends a minimum consumption of 200-500 mg of EPA+DHA for primary prevention of coronary illnesses, with greater dosages advised for individuals diagnosed with coronary heart disease. Nevertheless, the presence of zebra mussel as a raw material still contains beneficial health-promoting compounds. Besides, mussels have been recommended as a great nutritional supply of EPA and DHA for human consumers because of their vital role (Cherifi et al., 2018). Peycheva et al., (2021) reported 309.4 and 428.8 mg 100 g^{-1} EPA+DHA in *Mytilus galloprovincialis*. Panayotova et al. (2021) found the sum of DHA and EPA of *Mytilus galloprovincialis* varies between 250 and 650 mg 100 g^{-1}.

The Atherogenecity indice (AI) and thrombogenicity indice (TI) indices can be used as an alternate approach to evaluate the nutritional value of the lipid component in relation to human health. These indices are regarded as reliable indicators of the lipid quality in food, providing more accurate data in comparison to the PUFA/SFA ratio. Trombogenic and anti-trombogenic fatty acids interact, leading to the development of blood clots in the arteries in individuals with TI. Lower values of these indices indicate the presence of FAs that possess advantageous characteristics for preventing coronary heart disease, such as being anti-atherogenic and anti-thrombogenic. Therefore, fatty acids with lower values possess a higher capacity to inhibit the occurrence of coronary heart disease (Biandolini et al., 2023). Elevated levels of AI and TI have the potential to boost platelet aggregation and facilitate the development of blood clots (Peycheva et al., 2021). AI and TI values over 1.0 are deemed detrimental to human health and are strongly linked to the development of coronary heart disorders, mostly caused by the blockage of coronary channels due to atherosclerosis or thrombosis, either individually or in combination. Hence, lower numbers correspond to a higher level of protection against cardiovascular illnesses (Cherifi et al. (2018); Panayotova et al., 2021). In our investigation, we found that zebra mussel had AI and TI values below 1, which aligns with the findings of previous studies conducted with different mussel species by Panayotova et al. (2021); Prato et al. (2020); Moniruzzaman et al., (2021). The study found that the AI and TI values for animal meat were within the range of 0.5-1.0, which is notably lower than the values seen for lamb meat (1.87). The H/H index represents the ratio of hypercholesterolemic fatty acids to the total sum of fatty acids (Peycheva et al., 2021). The H/H fatty acid index is a valuable supplementary measure used to assess the impact of specific fatty acids on cholesterol metabolism (Prato et al., 2020). A higher H/H ratio corresponds directly to a higher amount of polyunsaturated fatty acids (PUFAs), which is regarded as more advantageous for human health in terms of nutritional value. Thus, higher H/H values in relation to nutrition are considered more beneficial for human health. (Prato et al., 2020; Zula and Desta, 2021). In the present study, H/H index was high. Prato et al., (2020) have found int their study that all species had values almost high within the range reported in the literature (0.25-3.23). In the present study, AI, TI and HH index of ZMO provides values that have positive effects on human health.

CONCLUSION AND RECOMMENDATIONS

It is crucial to have affordable food with a high lipid profile, not only for human consumption but also for the nutrition of farmed animals and pets. In modern times, there is a significant emphasis on functional diets, which not only supply essential nourishment but also offer health advantages and lower the likelihood of chronic illness. The findings of our current investigation demonstrate that the zebra mussel possess a high concentration of essential fatty acids that are necessary for maintaining human well-being.

Lipid extracted from zebra mussel exhibited fatty acid profile that were beneficial for human health. Results of the present study revealed the nutritional quality indices and beneficial fatty acids of zebra mussels for evaluation as nutraceutical and pharmaceutical food components. Accordingly, zebra mussel fatty acids provide health-promoting bioactive components that can be used in protecting human health and animal welfare and nutrition. However, further research is warranted to elucidate seasonal variations and other environmental condition in fatty acids and other nutritional components in zebra mussels.

Briefly, zebra mussel, which contains nutritionally beneficial fatty acids, is a species that is also highly resistant to environmental conditions, can multiply rapidly in fresh waters, and poses a risk for water flow by blocking channels, especially in dam lakes. Therefore, by processing zebra mussels, it can be an alternative oil source that can be used as nutraceutical and pharmaceutical, according to the beneficial fatty acids and good nutritional quality indexes revealed and management of dam lakes can be achieved by utilizing the zebra mussel, an invasive species, as an alternative oil source.

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REFERENCES

Biandolino, F., Prato, E., Grattagliano, A. & Parlapiano, I. (2023). Can Glyphosate and Temperature Affect the Nutritional Lipid Quality in the Mussel *Mytilus galloprovincialis*? *Foods*, ***12***, 1595. DOI: 10.3390/foods12081595

Bligh, G.E. & Dyer, J.W. (1959). A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol*., ***37***,(8), 911-7. DOI: 10.1139/o59-099

Cavali, J., Marmentini, P.R., Filho, D.V.J., Pontuschka, B.R. & Schons, S.V. (2022). Fatty acid profile, omegas, and lipid quality in commercial cuts of tambaqui (*Colossoma macropomum* Cuvier, 1818) cultivated in ponds. *Bol. Inst. Pesca*, ***48***, e700. DOI: 10.20950/1678-2305/bip.2022.48.e700

Chen, J. & Liu, H. (2020). Nutritional Indices for Assessing Fatty Acids: A Mini-Review. *Int. J. Mol. Sci.*, ***21***, 5695. DOI: 10.3390/ijms21165695

Cherifi, H., Ajjabi, C.L. & Sadok, S. (2018). Nutritional value of the Tunisian mussel *Mytilus galloprovincialis* with a special emphasis on lipid quality. *Food Chemistry*, ***268***, 307-314. DOI: 10.1016/j.foodchem.2018.06.075

EFSA. (2010). Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, *trans* fatty acids, and cholesterol. *EFSA Journal*, ***8***(3),1461.

Fonseca, F.V., Duarte, A.I., Matos, R.A., Reis Santos, P. & Duarte, B. (2022). Fatty acid profiles as natural tracers of provenance and lipid quality indicators in illegally sourced fish and bivalves. *Food Control*, ***134***, 108735. DOI: 10.1016/j.foodcont.2021.108735

Haldar, A., Dey, K.T., Dhar, P. & Chakrabarti, J. (2014). Exploring the Nutritive Values of the Fresh Water Mussel *Lamellidens marginalis* as Potential Functional Food. *Journal of Environmental Science, Toxicology and Food Technology*, ***8***(8), 01-07.

Keskinbalta, A.M. & Çelik, Y.M. (2020). Proximate Composition of Freshwater Mussels *(Unio Pictorum, Linnaeus 1758*) in Karasustream, Sinop. *Turkish Journal of Agriculture-Food Science and Technology*, ***8***(9), 1948-1951. DOI: 10.24925/turjaf.v8i9.1948-1951.3584

OIC. (2017). COI/T.20/Doc. No 33. Determination Of Fatty Acid Methyl Esters By Gas Chromatography, https://www.internationaloliveoil.org/wp-content/uploads/2019/11/COI-T.20-Doc.-No-33-Rev.-1-2017.pdf

Ozogul, F., Cagalj, M., Simat, V., Ozogul, Y., Tkaczewska, J., Hassoun, A., Kaddour, A.A., Kuley, E., Rathod, B.N. & Phadke, G.G. (2021). Recent developments in valorisation of bioactive ingredients in discard/seafood processing by-products. *Trends in Food Science and*

Technology, ***116***, 559-582. DOI: 10.1016/j.tifs.2021.08.007

Moniruzzaman, M., Sku, S., Chowdhury, P., Tanu, B.M., Yeasmine, S., Hossen, N.M., Min, T., Bai, C.S. & Mahmud, Y. (2021). Nutritional evaluation of some economically important marine and freshwater mollusc species of Bangladesh. *Heliyon*, ***7***, e07088. DOI: 10.1016/j.heliyon.2021.e07088

Nalepa, F.T., Cavaletto, F.J., Ford, M., Gordon, M.V. & Wimmer, M. (1993). Seasonal and Annual Variation in Weight and Biochemical Content of the Zebra Mussel, *Dreissena polymorpha*, in Lake St. Clair. *Journal of Great Lakes Research*, ***19***(3), 541-552. DOI: 10.1016/S0380-1330(93)71240-X

Panayotova, V., Merdzhanova, A., Stancheva, R., Dobreva, A.D., Peycheva, K. & Makedonski, L. (2021). Farmed mussels (*Mytilus galloprovincialis*) from the Black Sea reveal seasonal differences in their neutral and polar lipid fatty acids profile. *Regional Studies in Marine Science*, ***44***, 101782. DOI: 10.1016/j.rsma.2021.101782

Peycheva, K., Panayotova, V., Stancheva, R., Makedonski, L., Merdzhanova, A., Cicero, N., Parrino, V. & Fazio, F. (2021). Trace Elements and Omega-3 Fatty Acids of Wild and Farmed Mussels (*Mytilus galloprovincialis*) Consumed in Bulgaria: Human Health Risks. *Int. J. Environ. Res. Public Health*, ***18***, 10023. DOI: 10.3390/ijerph181910023

Prato, E., Fanelli, G., Parlapiano, I. & Biandolino, F. (2020). Bioactive fatty acids in seafood from Ionian Sea and relation to dietary recommendations. *International Journal of Food Sciences and Nutrition*, ***71***(6), 693-705. DOI: 10.1080/09637486.2020.1719388

Roy, V.C., Park, J. Ho, C.T. & Chun, B. (2022). Lipid Indexes and Quality Evaluation of Omega-3 Rich Oil from the Waste of Japanese Spanish Mackerel Extracted by Supercritical CO_2. *Marine Drugs*, ***20***, 70. DOI: 10.3390/md20010070

Santos-Silva, J., Bessa, R.J.B. & Santos-Silva, F. (2002). Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. *Livest. Prod. Sci*., ***77***, 187. DOI: 10.1016/S0301-6226(02)00059-3

Simat, V., Bogdanovic, T., Poljak, V. & Petricevic, S. (2015). Changes in fatty acid composition, atherogenic and thrombogenic health lipid indices and lipid stability of bogue (*Boops boops* Linnaeus, 1758) during storage on ice: Effect of fish farming activities. *Journal of Food Composition and Analysis*, ***40***, 120-125. DOI: 10.1016/j.jfca.2014.12.026

Şereflişan, H. & Ersoy Altun, B. (2018). Amino Acid and Fatty Acid Composition of Freshwater Mussels, *Anodonta pseudodopsis* and *Unio tigridis*. *Pakistan J. Zool.*, ***50***(6), 2153-2158. DOI: 10.17582/journal.pjz/2018.50.6.2153.21

Ulbricht, T.L. & Southgate, D.A. (1991). Coronary heart disease: seven dietary factors. *Lancet*, ***338***(8773), 985-92. PMID: 1681350. DOI: 10.1016/0140-6736(91)91846-m

Ullah, H., Gul, B., Khan, H. & Zeb, U. (2021). Effect of salt stress on proximate composition of duckweed (Lemna minor L.). *Heliyon*, ***7***, e07399. DOI: 10.1016/j.heliyon.2021.e07399

Zhukova, V.N. (2014). Lipids and Fatty Acids of Nudibranch Mollusks: Potential Sources of Bioactive Compounds. *Mar. Drugs*, ***12,*** 4578-4592; DOI: 10.3390/md12084578

Zula, T.A. & Desta, T.D., (2021). Fatty Acid-Related Health Lipid Index of Raw and Fried Nile Tilapia (*Oreochromis niloticus*) Fish Muscle. *Journal of Food Quality*, ***9***. Article ID 6676528, DOI: 10.1155/2021/6676528

WHO. (2010). Fats and fatty acids in human nutrition. Report of an expert consultation. Geneva: WHO/FAO.