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Indonesian freshwater fisheries' oil for health and nutrition applications: a narrative review

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Abstract

The consumption and production of freshwater fish in Indonesia have recently increased significantly, especially in the food sector. This is for health purposes due to the dietary content, including freshwater fish protein. Fish is not only a source of protein but also a considerable supply of polyunsaturated fatty acids (PUFAs) and is essential. Using fish oils has caught a growing interest due to an increased understanding of the possible health benefits of omega-3 fatty acids in humans. This review provided thoughts on progress in the research of Indonesia's freshwater fisheries' oil potential. Here, fish oil's potential was addressed through its outstanding biochemical features and its potential as an anti-inflammatory, cardiovascular, cancer, and autoimmune disorder agent. Generally, nutritional properties, their possible application in food production, and therapeutic and socioeconomic significance are considered. Indonesian freshwater aquaculture fisheries and inland capture fisheries have the potential for refined fish oil production. The top freshwater fisheries include aquaculture (*Oreochromis niloticus*, *Clarias, Cyprinus carpio*, *Pangasius*, and *Osphronemus goramy*) and inland capture fisheries (*Channa striata*, *Oreochromis niloticus*, *Trichogaster*, *Hemibagrus capitulum*, and *Pangasius*). Indonesian fish oil is rich in omega-3 fatty acids, especially eicosapentaenoic acid and docosahexaenoic acid, and can potentially be developed into drugs and food supplements.

1. Introduction

Indonesia is one of the ten member states of the Association of the Southeast Asian Nations' economically and politically diverse regional body (Von Rintelen *et al*., 2017). The country is also known for the highest diversity of flora and fauna in Southeast Asia (Webb *et al*., 2010; Idrus *et al*., 2019). The rich natural resources of Indonesia can improve human health, particularly in the areas of nutrition, antidiabetic medicines (Nugroho *et al*., 2014; Sasongko *et al*., 2020), the immune system (Sujono *et al*., 2021), cardiovascular disease (Trilestari *et al*., 2015; Wigati *et al.,* 2017), and others. Indonesia's geographical location and the availability of water supplies provide a tremendous opportunity for fishing resources from the natural water bodies (Sunoko and Huang, 2014). It offers Indonesia a preferential edge in undertaking catches (Wicaksono *et al*., 2020). The Indonesian archipelago with more than 17,500 islands has various fishing sources extending from the Pacific to the Indian Ocean (Priatni *et al*., 2018). Indonesia is the second-largest source of marine capture fisheries worldwide in the latest Food and Agriculture Organization (FAO) Landings Statistics (FAO, 2018). The significant problem with the biological effect on aquatic biodiversity has now been fishing production. Based on the Badan Pusat Statistik (BPS) Indonesia data, marine fishery production had increased from 657,691.74 tons in 2017 to 816,945.30 tons in 2019. In 2017, fishery production by type of cultivation (sea, fish ponds, reservoir, nets, and rice fields) amounted to 16,114,991 tons (BPS, 2020). A large amount of fish production is a significant capital for Indonesia to be developed as a health product other than as food for consumption (Sasongko *et al*., 2017). The information on the substance of fish nutrition can provide essential guidance on seafood consumption and

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human health safety (Zhang *et al*., 2020).

In future decades, global demands for food from the fisheries world are projected to rise, as these foods will help satisfy the needs and desires of a rising human population. Median estimates indicate a global population increase of 2.4 billion by 2050 to over 9.7 billion (United Nations, 2015). The high nutritious fish content is one of the main foods in the human diet to maintain, restore, and stimulate growth (Jennings *et al*., 2016; Venugopal and Gopakumar, 2017). Micro and macronutrients that are also important for nutritional health are categorized into nutrients (Santeramo and Shabnam, 2015). The fish is filled with macronutrients including nutrition, lipid, ash, and carbohydrates (Lilly *et al*., 2017). About 16.7% of animal protein ingested by humans in 2010 was produced by fish from marine and freshwater ecosystems. Fish protein accounted for 20% of the needed per capita consumption of animal protein for 2.9 billion individuals. In recent decades, the proportion of global fish supply consumed by humans has risen to 86%. The remaining 14% is for other uses, including fish meal and oil production, which, while used in fish and animal feed, contribute indirectly to human food production (FAO, 2014). This study states that the administered fish protein hydrolysates are a valuable supply of low fat and biogenic amine protein, essential amino acids, and antioxidants (Alvares *et al*., 2018). Many fishery resources in Indonesia have used this protein as a supplement or for nutrient purposes. Based on some recent studies, the protein from *Channa striata* is known to have the potential for wound healing (Rahayu *et al*., 2016; Sasongko *et al*., 2018) and reduces pain (Ab Wahab *et al*., 2015), while protein from scad fish has an antioxidant potential (Chen *et al*., 2020; Hu *et al*., 2020). Enzymes from *Oreochromis niloticus* are used for fish sauce and as a laundry detergent additive (Villamil *et al*., 2017).

Fish, not only as a protein source but also as a considerable supply of polyunsaturated fatty acids (PUFAs), is an essential component for health (Fard *et al*., 2019; Yang *et al*., 2020). Fish oil has been widely studied in the development of food supplements and drugs. They are the renowned source of a group of PUFAs (Mason and Sherratt, 2017; Pal *et al*., 2018). The crucial role that fatty acids play in membrane components, energy, metabolism, and signage mediators is essential to life (Pereira *et al*., 2013). PUFAs are 18 or more carbon-containing fatty acids with more than one double bond. The PUFAs are further classified into three groups: omega-3 PUFAs, omega-6 PUFAs, and omega-9 PUFAs, based on the last dual-bond relative to the end-of -molar methyl. Among them are essential fatty acids omega-3 PUFAs and omega-6 PUFAs that cannot be synthesized in mammals (Zhang *et al*., 2020). In recent decades, biomedical proof has been given for the safety of omega-3 PUFAs in epidemiological and experimental studies. Specifically, eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) play a significant role in deterring many diseases (Simmonds *et al*., 2020). The increasing amount of data has contributed to the guidelines from the Food and Drug Administration (FDA) about the intake of seafood/fish and/or their dietary supplementation with omega-3 PUFA (Goel *et al*., 2018). In 2012, the United States (US) FDA approved a prescription fish oil formula. Fish oil continues to be the most common natural supplement in the US, used by almost 18.8 million adults (Clarke *et al*., 2015).

This review will provide thoughts on progress in the research of Indonesia's marine fisheries' oil potential. Here, fish oil potential is addressed through outstanding biochemical features, with free radicals and anti-inflammatory effects against cancer, cardiovascular diseases, and autoimmune disorders. Nutritional properties, their possible application in food production, therapeutic characteristics, and socioeconomic significance in general, are considered. The prospects explore their importance in the battle against hunger, to improve health, and expand the food sector in local and global markets.

2. Indonesian freshwater fisheries production

The Indonesian marine fishery production data are based on data statistics from the Ministry of Marine Affairs and Fisheries (MMAF) in 2015–2017 for inland capture fisheries and 2017–2020 for aquaculture fisheries. The inland capture fisheries data accessed at the end of December 2020 shows that the amount of Indonesian fishery production was last available in 2018, while in 2019–2020 no single data was found. Integrated marine and fisheries production data were obtained at the MMAF centre data, statistics, and information since 2017. Data were obtained primarily in the field using the survey method, taking samples in every district or city throughout Indonesia. The sample frame is taken from the listing of marine and fishery business actors based on a specific stratification type in each district. Data were collected daily (production at the fishing port), weekly (fish prices), and monthly (MMAF, 2020). The amount of fishery production in Indonesia is divided into three sources: sea catch, cultivation, and inland public waters. The top five Indonesian fishery products based on data from the Ministry of Fisheries and Maritime Affairs are presented in Figures 1 and 2. The amount of fish production in 2018–2020 is likely to increase based on the previous years' production trend. Encountering shifts in the form and quantity of fish produced is also possible, which is seen from the ministry's always moving data.

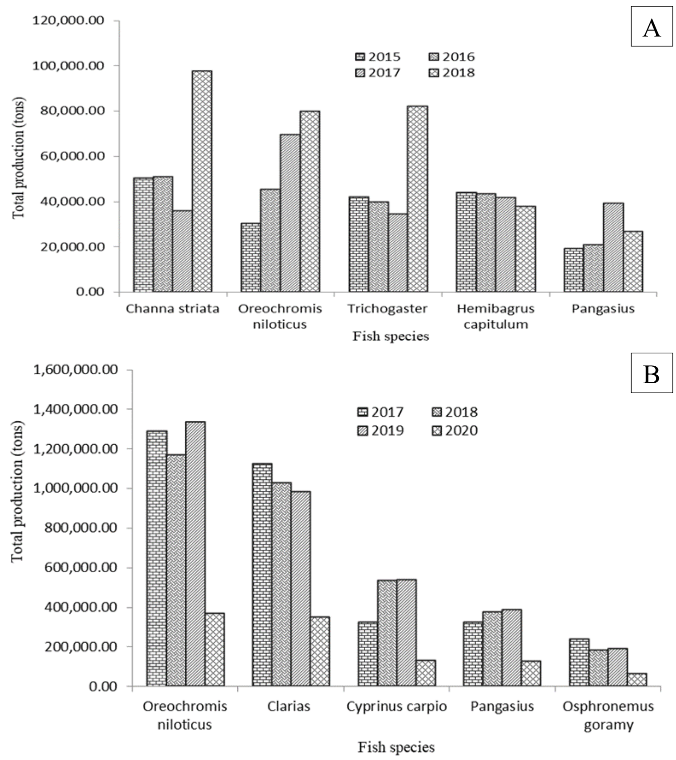

Figure 1. The top five Indonesian fish produce based on the Ministry of Marine Affairs and Fisheries. A: Inland capture fisheries and B: aquaculture fisheries (MMAF, 2020).

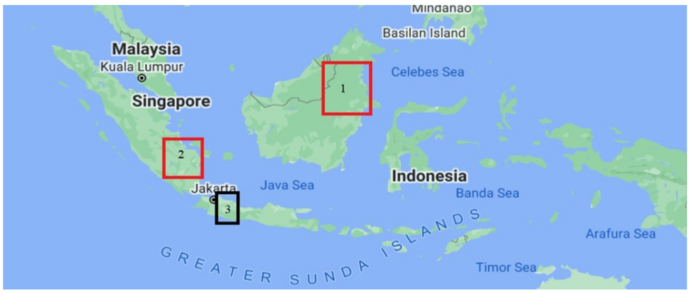

Figure 2. The top three fish production provinces in Indonesia based on the Ministry of Marine Affairs and Fisheries. 1: South Kalimantan (2018), 2: South Sumatra (2015–2017) (*Channa striata* inland capture fisheries), and 3: West Java (*Oreochromis niloticus* aquaculture fisheries production) (MMAF, 2020).

3. Biochemical composition of fish oil

Eating fish is seen to be part of a healthy and balanced diet. Globally, marine animals cover the overall production for capture and aquaculture, of which 86% were used for direct human consumption (Rittenschober *et al.*, 2013). Due to the discoveries of the health benefits of omega-3 fatty acids, particularly EPA and DHA, the demand for fish oil in the pharmaceutical industry has been growing in recent years. Fish oils are unique in the number of fatty acids they are made up of and are an outstanding source of biologically essential highly unsaturated omega-3 fatty acids. In the past, fish oil has been mostly used in aquaculture feed, is a critical ingredient, and has also been used in livestock feed, including poultry and swine. The use of fish oils for human use has a growing interest due to increasing awareness of the possible health benefits of omega-3 fatty acids in humans (Rizliya and Mendis, 2014). The level of fish-eating cannot be separated from the active compound or nutrients found within. The chemical composition of fish oil is essential for basic research and knowledge development in fish species studies including physiology, biochemistry, ecology, conservation, and pharmaceutical industrial development (Priatni *et al.*, 2018). Fatty acids obtained from fish oils are divided into saturated, monounsaturated, and polyunsaturated groups (Devers and Brown, 2020). Fish oil compounds from one country or territory to another can be different. The content of fatty acids in fish was dependent on their feed and was influenced by their height, age, and reproductive and environmental factors, particularly water temperatures that could impact the lipid content and fatty acid composition (Nurnadia *et al.*, 2011). According to Goel *et al.* (2018), the structure of major PUFAs and their metabolism (PUFAs) is depicted in Figure 3. Compared with other oils, fish oils contain a unique range of unsaturated fatty acids in more significant numbers (Rizliya and Mendis, 2014). Fatty acid properties in the top five inland capture fisheries and aquaculture can be seen in Table 1.

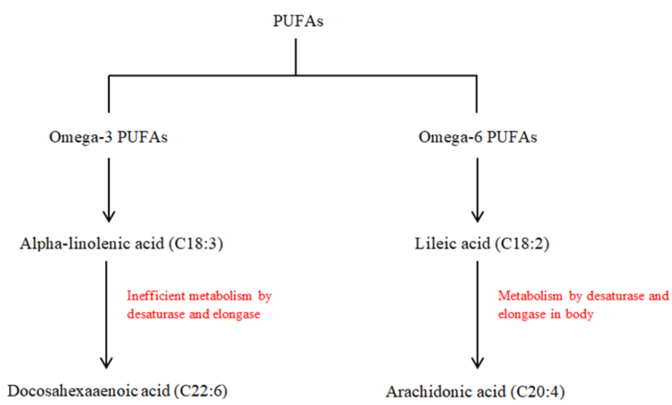

Figure 3. Structure of major polyunsaturated fatty acids and their metabolism (PUFAs) (Goel *et al*., 2018).

4. Fish oil physical and chemical quality

The chemical properties are considered for the food, feed, and medicinal industries worldwide because fish oil is a favoured raw material. Through their physical form, fish oils are very identical to one another. At room temperature, they are fluid and are known as liquid oils. However, because of the presence of intermediate melting point triglycerides, the oil is partly stable at 20°C. Solid triglyceride crystals are formed as liquid oil is slowly cooled, and the crystallization continues as cooling is continued. This is the cornerstone of crystallizing fractionation (Rizliya and Mendis, 2014).

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Table 1. Fatty acid profiles of Indonesia's top five freshwater fish species

Indonesian fish name/*species*	Fatty acids	Value % w/w			Extraction method	Sample source	References
		1	2	3			
Channa striata	Omega-3 Omega-6 Omega-9	3.25 11.03 28.89	7.83 10.88 41.31	18.3 11.9 27.2	1. Pressurized boiling oil 2. Maceration with petroleum benzene solvent 3. Fillets are blended with methanol and chloroform solvent	1. Papua 2. N/A 3. North Sulawesi	1. Pasaribu *et al.* (2020) 2. Putri *et al*. (2019) 3. Pontoh and Tumiwa (2018)
Oreochromis niloticus	Omega-3 Omega-6 Omega-9	18.96 27.9 8.9	18.68 5.32 22.63		1. Fermented with 2.5% Lemna minor 2. Soxhletation and purification using activated charcoal and bentonite	3. Central Java 4. Central Java	5. Herawati *et al.* (2020) 6. Sumartini *et al.* (2019)
Trichogaster	Palmitic acid Oleic acid Linoleic acid	21.74 17.89 6.88			N/A	South Borneo	Adawyah *et al*. (2020)
Hemibagrus capitulum	Omega-3 Omega-6 Omega-9	4.03 13.71 27.02			Smoked	Kampar River, Riau	Jippo Maskilin *et al*. (2017)
Pangasius	Omega-3 Omega-6 Omega-9	1.35 10.32 29.26	3.08 16.47 31.99	0.79 11.87 34.18	1. Fresh fillet 2. Maceration with petroleum benzene solvent 3. Dry rendering method at 100°C	1. South Sumatra 2. N/A 3. Central Java	4. Sudirman *et al.* (2018) 5. Putri *et al*. (2019) 6. Lestari *et al*. (2020)

Carotenoids are the pigments that give commercial fish oils their red and yellow colour. Menhaden oil contains alpha- and gamma-carotene, zeaxanthin, violaxanthin, and xanthophyll; pilchard oil contains fucoxanthin and xanthophyll; and capelin oil contains astaxanthin, which is responsible for the pink hue. Despite the presence of carotenoids, the pigments observed are not carotenoids (Young, 1986). The physical characteristics of fish oil allowed by BPOM Indonesia, FAO, and the Indonesian national standards are presented in Table 2.

5. Fish oil extraction method

Many studies have been conducted to examine the extraction process in obtaining fish oil. Green extraction is an extraction method that decreases energy consumption, making the use of substitute solvents and sustainable natural substances possible, and offering a clean, high-quality extract or product, thus fulfilling the concept of circular bioeconomy (Barakova *et al*., 2016; Runge *et al*., 2017). The six key strategies have been described as an approach to optimize the use of raw materials, solvents, and resources to build and produce a green extraction laboratory or provide green extraction on an industrial scale: (1) innovation by choosing varieties and using natural energy, (2) application of substitute solvents, primarily water or agro-solvents, (3) reducing energy use by recovering energy and making use of advanced technologies, (4) creation of co-products for the bio- and agro-refining industry rather than waste, (5) decreasing unit activities and facilitating healthy, robust, and regulated processes, and (6) objective of a non-denatured and biodegradable extract without contamination (Chemat *et al*., 2012). Fish oil accounts

Table 2. Quality and safety requirements for refined fish oil

Parameters	Nonfood Source: MMAF (2019)	Docosahexaenoic acid oil derived from fish oil Source: BPOM RI (2011)	Fish oils, fish liver oils, concentrated fish oils, and concentrated fish oils ethyl esters Source: FAO (2017)
Chemical:			
Iodine value	>120 m/yod	Min 190 (g I_2/100 g)	
Acid value	<3 mg KOH/g	Max 0.6 mg KOH/g	≤3 mg KOH/g*
Peroxide value	<5 meq O_2/kg	Max 5 meq O_2/kg	≤5 meq of active oxygen/kg oil*
Anisidine value	<20 mEg/kg	Max 15	≤20
Saponification value	<26 APM/g	Min 195 mg KOH/g	
Totox value		Max 19	≤26
Unsaturated value		Max 2	
Microbiological contamination:			
E. coli bacteria	<3 APM/g		
Salmonella bacteria	Negative/25 g		
Heavy metal contamination:			
Mercury (Hg)	<0.1 mg/kg	<0.1 ppm	
Plumbum (Pb)	<0.1 mg/kg	<0.1 ppm	
Cadmium (Cd)	<0.1 mg/kg	<0.1 ppm	
Arsenic (As)	<0.1 mg/kg	<0.1 ppm	
Polychlorinated biphenyls (PCB)	Max 0.09 mg/kg		
Foreign object	0		
Chemical contamination:			
Total dioxins and furans		Max 2 (pg WHO-PCDD/F-TEQ/g fat)	
Total dioxins, furans, dioxin-like PCB-s		Max 10 (pg WHO-PCDD/F-PCB/g fat)	
Benzo *(a)* pyrene		Max < 2 ppb	
Total pesticides:			
Endosulfan (α,β-isomer) Endosulfan sulfate Esfenvalerate		Max 0.1 ppm as endosulfan	
Chlordane Oxychlordane		Max 0.2 ppm as chlordane	
Dichlorodiphenyltrichloroethane (DDT) Dichlorodiphenyldichloroethane (DDD) Dichlorodiphenyldichloroethylene (DDE)		Max 0.005 ppm as DDT	
Heptachlor (α,β-isomer) Heptachlor epoxide Benzene hexachloride		Max 0.2 ppm as heptachlor	
General characteristics		Yellow color and smell fish distinctive	
Docosahexaenoic acid		Min 210 mg/g	
Docosahexaenoic acid:eicosapentaenoic acid ratio		4:1	
Total omega-3 fatty acid		Min 265 mg/g	
Total omega-6 fatty acid		Max 100 mg/g	
Trans-fatty acid		Max 2 %	
Protein residue		Negative	
Moisture		Max 0.1 %	
Ascorbyl palmitic		Max 5000 ppm	
Tocopherol		Max 5000 ppm	Max 6000 mg/kg, individually or in combination
Vitamin A		Max 100 IU/mL	≥40 µg of retinol equivalents/mL of oil**
Vitamin D		Max 50 IU/mL	≥1.0 µg/mL**
Cholesterol		Max 10 mg/g	

* Exception of fish oils with a high phospholipid concentration of 30% or more.

** Maximum levels for vitamins A and D should be according to the needs of each individual country including, where appropriate, the prohibition of the use of particular vitamins.

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for about 2% of the fats and oils eaten worldwide, which is historically obtained as a byproduct of the fish meal industry (Rizliya and Mendis, 2014). Therefore, studies into new sources or ecosystems in various areas of the world, reducing the environmental effects of extraction methods, and incorporating green extraction methods on an industrial scale have been illustrated over the last decade (Ivanovs and Blumberga, 2017). Depending on the form of raw material, the manufacturing methods used in the commercial production of fish oils differ from each other. A variety of techniques have been used to turn raw fish and fish trimmings into fish oil (Rizliya and Mendis, 2014).

6. Bioactivity fish oil

With new types of diseases on the rise globally, more people are motivated to maintain good health, and as a food supplement, fish oil can contribute to that (Abou-Saleh *et al*., 2019). Significant concentrations of omega-3 fatty acids, including EPA and DHA, are present in fish oil, which is essential for humans (Setty *et al*., 2019). In many human uses, including nutrition, pharmaceuticals, vitamins, and functional foods, fish oil is used mainly as a food supplement (Mengelberg *et al*., 2018). In the body, omega-6 and omega-3 PUFAs have competing effects. Omega-6-rich diets are precursors to inflammation-related eicosanoids, vasoconstriction, and platelet aggregation (Dennis and Norris, 2015). A defensive response to infection and injury is acute self-limited inflammation. However, atherosclerosis and cancer have been associated with overly inappropriate inflammation. Omega-3 PUFAs, however, are precursors to anti-inflammatory molecules that have benefits for chronic inflammatory diseases, including diabetes, cancer, and ischemic heart disease (Saini and Keum, 2018). The top five Indonesian freshwater fish (*Channa striata, Oreochromis niloticus, Trichogaster, Hemibagrus capitulum,* and *Pangasius)* have the potential for fish oil production development. Several studies suggest that their composition, omega-3 fatty acid, can be used as a medicine or health supplement. The high nutrition in *Channa striata* gives this fish ability to avoid stunting as a nutrient-rich food (Pasaribu *et al*., 2020). It was useful for inhibiting pathogenic bacteria including *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* as antimicrobial therapy (Achmad *et al*., 2020). The extract of *Channa striata* fillet is known to have a hepatoprotective effect in a rat model induced by oxidative stress (Suhartono *et al*., 2013). The omega-3 and omega-6 fatty acids found in the *Channa striata* are useful as nutrients in speeding the wound healing process (Daisa *et al*., 2017; Sasongko *et al*., 2018) by increasing fibroblast cells and collagen density (Hendriati *et al*., 2019). *Channa striata* can use its compound as an angiotensin-converting enzyme inhibitor and antidepressant for metabolic disorders and as a neuroregenerative agent for conventional use as a wound healer, pain reliever, and energy booster. The fish seems to have wide-ranging medicinal applications and should be more intensively researched to explore its other properties and modes of action (Shafri and Abdul Manan, 2012). Including *Channa striata*, the fish oil from *Oreochromis niloticus, Trichogaster, Hemibagrus capitulum,* and *Pangasius,* is also known for its fatty acid content (Putri *et al*., 2019; Irnawati *et al*., 2021). The dose of 72.8 mg/kg of catfish (*Pangasius*) oil extracts was the most efficient in reducing blood glucose and healing necrotic islands of Langerhans (Hidayaturrahmah, 2017). In other fish oil studies, salmon oil is known to have an effect on cardiovascular health (de Roos *et al*., 2021). Cod liver oil reduces total cholesterol and low-density lipoprotein levels in patients with hyperlipidemia (Fatima *et al*., 2021). The ratio of omega-3 fatty to omega-6 and other fatty acids has the potential biological activity that must be studied. Some critical biological pathways are modulated by omega-3 fatty acids, including EPA and DHA, with many research lines indicating at least some differential benefits. In human tests, both fatty acids lower triglyceride levels and collagen-stimulated platelet aggregation and favourably influence cardiac diastolic filling, arterial compliance, and at least some inflammatory and oxidative stress parameters based on small numbers of studies (Mozaffarian and Wu, 2012). For the prevention of joint pain associated with many inflammatory disorders and against bone loss during ageing (Abou-Saleh *et al*., 2019), omega-3 PUFAs have been used (Goldberg and Katz, 2007; Layé *et al*. 2018).

7. Conclusion and future perspective

Indonesia is a massive land–water archipelago that produces large freshwater fisheries. Inland capture fisheries contain fatty acids, which are suitable for development as a health supplement or medicine. The use of inland fishing tools for human consumption has increased rapidly in Indonesia in recent years. The recognition of the health benefits of PUFAs, particularly those of families with a high proportion of fish species with high-fat content, has been further increased by this. The top five Indonesian fisheries have seen productivity improvement. The weather should not affect inland fisheries' goods that much, with the harvest being different from the sea catch. The use of fish oil has risen significantly in the food and pharmaceutical sectors, where demand tends to stagnate. The future use of fish oil in adjuvant therapy in the case of global diseases such as coronavirus disease 2019 and others allowed for

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increasing fish oil demand. Fish oil production from inland fisheries is one solution that medicinal products have started to appear on the market using freshwater fish as raw material. In addition to freshwater fish used as food, processing by-products can be utilized by the food industry that uses fish to produce fish oil. Besides catches in public land waters, freshwater fish can also be cultivated so that production can increase.

Conflict of interest

The authors declare no conflict of interest.

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