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Fatty Acid Profiling of Fish Oil from Siro (*Amblygaster sirm*) and Tembang (*Sardinella fimbriata*) of West Sumbawa

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Abstract: West Sumbawa waters possess abundant marine resources dominated by small pelagic fish species, including Siro (*Amblygaster sirm*) and Tembang (*Sardinella fimbriata*). However, information regarding the fatty acid profiles of these local fish remains limited. This study aimed to characterize the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) in oils extracted from both species. Fish oil was extracted by maceration using an *n*-hexane:isopropanol solvent mixture (3:2, v/v), followed by fatty acid analysis using Gas Chromatography–Mass Spectrometry (GC–MS). The results showed that both fish oils were rich in long-chain polyunsaturated fatty acids (LC-PUFAs), predominantly docosahexaenoic acid (DHA, C22:6), reaching 23.25% in Siro and 21.04% in Tembang fish oil. Arachidonic acid (ARA, C20:4) was also detected at relatively balanced levels (9.66% and 9.52%, respectively), whereas eicosapentaenoic acid (EPA, C20:5) remained low (<1%). Palmitic acid (C16:0) predominated within the SFA fraction (~28.1%). These findings highlight the potential of fish oil from both species as a valuable source of functional ingredients for food fortification and nutraceutical applications.

Keywords: Extraction; Fish; Fortification; Lipids; Nutraceuticals

Introduction

West Sumbawa is one of the regencies in Indonesia with abundant marine resources. Various groups of captured fisheries dominate this region, including pelagic, demersal, crustaceans, and mollusks. Among these, small pelagic fish such as siro (*Amblygaster sirm*) and tembang (*Sardinella fimbriata*) represent the dominant catches. In 2023, the recorded landings of siro (*Amblygaster sirm*) reached 57.8%, while tembang (*Sardinella fimbriata*) accounted for 36.49%.

Fish are recognized as an excellent source of lysine and sulfur-containing amino acids (methionine and cysteine), which are not found in plant-based proteins (Maurya et al., 2018).In addition, fish are well known for their content of essential omega-3 fatty acids (Cholewski et al., 2018). A study conducted by Kudale and Rathod (2015) reported that tembang (*Sardinella fimbriata*) obtained from Karwar waters contained a relatively complex nutrient composition, including moisture (68.74%), protein (15.99%), lipid (10.29%), carbohydrate (0.39%), and ash (6.78%). Fish oil is defined as oil extracted from fish tissues, which is rich in essential fatty acids (Das et al., 2024). It contains a high proportion of polyunsaturated fatty acids (PUFAs), particularly omega-3 fatty acids such as α-linolenic acid (ALA; 18:3), eicosapentaenoic acid (EPA; 20:5), and docosahexaenoic acid (DHA; 22:6), as well as omega-6 fatty acids such as conjugated linoleic acid (CLA) and arachidonic acid (Das et al., 2024; Kaur et al., 2014; Khawar Balwan et al., 2021). Due to its high PUFA content (both omega-3 and omega-6), fish oil is considered a functional food, contributing to the maintenance of human health (Cholewski et al., 2018; Das et al., 2024; Sultana et al., 2023). The consumption of fish oil provides more

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optimal nutritional benefits compared to the direct consumption of fish.

Exploration of fish oil derived from pelagic species has previously been reported by (Šimat et al., 2020), who demonstrated that sardine oil (*Sardina pilchardus*) contains rich profiles of essential fatty acids, including well-balanced saturated and polyunsaturated fatty acids. In particular, it contains significant amounts of omega-3 fatty acids such as eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3). Similar exploration has also been conducted on *Sardinella sp.*, where fish oil extracted and purified using citric acid and NaCl demonstrated significant reductions in peroxide value, free fatty acids, p-anisidine, and TOTOX by 72.42–92.37%, 77.95–85.83%, 5.43–51.90%, and 49.59–76.99%, respectively (Šimat et al., 2020). However, further efforts are still required to explore fish oil from other pelagic species. To date, the fatty acid composition of siro (*Amblygaster sirm*) and tembang (*Sardinella fimbriata*) has not been reported. Investigating these local species is crucial to establishing baseline geographical lipid data and evaluating their potential compared to other global pelagic resources. Therefore, this study was conducted to determine and characterize the definitive fatty acid profile, including saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA), of siro and tembang fish oils.

Method

Sample Preparation

Fresh samples of siro (*Amblygaster sirm*) and tembang (Sardinella *fimbriata*) were collected from local fish landing sites in West Sumbawa. The fish were transported in ice and stored at –19 °C prior to analysis. The fish were cleaned and separated into edible portions. Approximately 20 g of homogenized fish tissue was used for each extraction replicate.

Fish Oil Extraction

Fish oil extraction was performed by maceration following the method described by (Iberahim & Tan, 2020) with slight modifications. Fish oil was extracted by maceration using a solvent mixture of *n*-hexane and isopropanol (3:2, v/v). Fresh fish samples were cleaned, weighed 20 g, and homogenized for 30 s with the solvent mixture. The homogenate was incubated in a water bath at 70 °C for 15 min and subsequently centrifuged at 3000 rpm for 10 min. The supernatant was collected and passed through anhydrous sodium sulfate to remove residual moisture, then filtered and separated using a separatory funnel. The organic phase was evaporated under reduced pressure with a rotary evaporator until all solvents were removed, yielding crude fish oil. The oil obtained was directly used for fatty acid analysis by GC–MS

Result and Discussion

The characterization of total fatty acids in Siro fish oil (Amblygaster sirm) and Tembang fish oil (*Sardinella fimbriata*) was classified into three major fractions, namely saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA). Based on the analytical results, both small pelagic fish species exhibited the predominance of SFA and long-chain polyunsaturated fatty acids (LC-PUFA), indicating a lipid composition profile commonly observed in tropical marine pelagic fish.

The PUFA fraction in both fish oils was predominantly composed of docosahexaenoic acid (DHA, C22:6) as the major component. The DHA content in Siro fish oil reached 23.25%, which was slightly higher than that of Tembang fish oil (21.04%). The high proportion of DHA indicates that both species have considerable potential as natural sources of omega-3 fatty acids with high functional value. DHA is known to play an essential role in nervous system development, cognitive function, retinal health, and protection against cardiovascular diseases (Calder, 2015). The accumulation of DHA in marine fish is also associated with the transfer of omega-3 fatty acids through the aquatic food chain originating from microalgae and phytoplankton as primary producers (Glencross et al., 2020).

Compared with previous studies on Siro fish (*Amblygaster sirm*) collected from Muara Angke waters, Jakarta (Suseno et al., 2014), where the reported DHA content was 18.99%, the DHA level observed in the present study was higher. This difference indicates spatial variation in fatty acid profiles influenced by environmental conditions. Fish lipid profiles are influenced by environmental factors, including water temperature, primary productivity, nutrient availability, and dietary sources, while phytoplankton and microalgae act as primary producers of omega-3 fatty acids in aquatic food webs (Maltsev & Maltseva, 2021; Xu et al., 2020) Differences in DHA accumulation may also be associated with environmental conditions influencing primary productivity and the availability of natural feed sources, such as phytoplankton and microalgae, which serve as the primary producers of omega-3 fatty acids in aquatic ecosystems (Fernandes et al., 2021; Glencross et al., 2020; Maltsev & Maltseva, 2021)

Table 1. Screening results of fatty acids in siro and tembang fish oil

Fatty Acid Component	Siro (%)	Tembang (%)
Saturated Fatty Acids (SFA)		
- Lauric acid (C12:0)	0.31	0.31
- Myristic acid (C14:0)	6.18	11.78
- Palmitic acid (C16:0)	28.11	28.15
- Stearic acid (C18:0)	11.76	10.02
- Arachidic acid (C20:0)	0.25	0.34
- Heneicosanoic acid (C21:0)	0.16	0.19
- Behenic acid (C22:0)	0.24	0.28
Monounsaturated Fatty Acids (MUFA)		
- Myristoleic acid (C14:1)	0.19	0.42
- Palmitoleic acid (C16:1)	4.85	7.46
- Oleic acid (C18:1)	5.72	3.53
- Gondoic acid (C20:1)	0.84	-
- Nervonic acid (C24:1)	0.84	0.52
Polyunsaturated Fatty Acids (PUFA)		
- Linoleic acid (C18:2)	2.43	-
- Linolenic acid (C18:3 cis 6,9,12)	0.87	1.57
- Linolenic acid (C18:3 cis 9,12,15)	0.37	-
- Eicosadienoic acid (C20:2)	0.32	0.25
- Eicosatrienoic acid (C20:3 cis 8,11,14)	2.58	3.70
- Eicosatrienoic acid (C20:3 cis 11,14,17)	0.68	0.63
- Arachidonic acid (C20:4)	9.66	9.52
- Eicosapentaenoic acid / EPA (C20:5)	0.44	0.36
- Docosahexaenoic acid / DHA (C22:6)	23.25	21.04

In addition to DHA, arachidonic acid (ARA, C20:4) belonging to the omega-6 group was also detected at relatively high and balanced concentrations in both species, accounting for 9.66% in Siro fish and 9.52% in Tembang fish. The presence of DHA and ARA indicates that both fish oils contain considerable amounts of omega-3 and omega-6 polyunsaturated fatty acids (PUFAs). In biological systems, DHA plays an important role in nervous system development and cognitive function, whereas ARA serves as a precursor of eicosanoids involved in immune regulation, inflammation, and various cellular physiological processes (Calder, 2020; Joffre et al., 2020)

Another PUFA component, eicosapentaenoic acid (EPA, C20:5), was detected at relatively low levels, accounting for 0.44% in Siro fish and 0.36% in Tembang fish. These values were comparable to those reported for Siro fish from Muara Angke waters, which showed an EPA content of 0.45% (Suseno et al., 2014), suggesting that tropical small pelagic fish generally exhibit low EPA levels (<1%). The relatively low EPA content observed in the fish oils may be associated with lipid metabolic pathways in tropical marine fish, in which EPA serves as an intermediate precursor that undergoes elongation and desaturation to form DHA, thereby resulting in greater DHA accumulation in fish tissues (Monroig et al., 2022). In addition, environmental temperature may influence membrane lipid composition and fatty acid requirements, as aquatic organisms inhabiting colder waters generally require higher levels of unsaturated fatty acids to maintain membrane fluidity and physiological function (Colombo et al., 2017)

This characteristic differs from that of pelagic fish inhabiting subtropical and cold-water regions. In low-temperature environments, fish generally accumulate higher levels of long-chain polyunsaturated fatty acids (PUFAs), particularly EPA, to maintain membrane fluidity and support physiological functions under colder conditions (Colombo et al., 2017). Previous studies on subtropical pelagic fish have reported EPA levels ranging from 4–9% (Usydus et al., 2011). Therefore, the predominance of DHA accompanied by relatively low EPA levels observed in the present study suggests a distinct lipid deposition pattern in tropical pelagic fish and highlights their potential as a promising source of DHA-rich fish oil.

Several minor PUFA components, including eicosatrienoic acid (C20:3) and eicosadienoic acid (C20:2), were detected with different distributions between the two fish species. Siro fish oil contained linoleic acid (C18:2) at 2.43% and linolenic acid (C18:3 cis-9,12,15) at 0.37%, whereas these fatty acids were not detected in Tembang fish oil. In contrast, the linolenic acid isomer (C18:3 cis-6,9,12) was present at a higher concentration in Tembang fish oil (1.57%) than in Siro fish oil (0.87%). These variations may reflect differences in lipid metabolic pathways, particularly in the activity of desaturase and elongase enzymes involved in the biosynthesis of unsaturated fatty acids (Monroig et al., 2022). Furthermore, differences in natural feed availability and composition, including microalgae and plankton communities, may also contribute to the observed variation in PUFA profiles between the two species (Glencross et al., 2020).

The MUFA fraction in both fish oils was primarily dominated by palmitoleic acid (C16:1) and oleic acid (C18:1). Tembang fish oil exhibited a higher palmitoleic acid content, whereas oleic acid was more abundant in Siro fish oil. Variations in the proportions of these fatty acids may be associated with differences in Δ9-desaturase activity, an enzyme involved in the conversion of saturated fatty acids into monounsaturated fatty acids (Glencross et al., 2020). In addition to serving as metabolic energy reserves, MUFAs also play important roles in maintaining membrane fluidity and lipid stability. Several minor MUFA components, including myristoleic acid, nervonic acid, and gondoic acid, were also identified in both fish species at varying levels, suggesting differences in fatty acid elongation and lipid metabolic pathways (Monroig et al., 2022).

The saturated fatty acid (SFA) fraction in both species was dominated by palmitic acid (C16:0) as the major component. The palmitic acid contents in Siro and Tembang fish were relatively similar, accounting for 28.11% and 28.15%, respectively. The high proportion of palmitic acid indicates that both species exhibit relatively similar lipid metabolic patterns, considering that palmitic acid is the primary product of the *de novo* lipogenesis pathway and functions as an energy source and structural component of fish tissue lipids (Glencross et al., 2020)

Compared with previous studies on Siro fish collected from Muara Angke waters, which reported palmitic acid levels ranging from 16–19%, the values obtained in the present study were considerably higher. This variation may indicate that saturated fatty acid accumulation is influenced by environmental conditions, including primary productivity, natural feed composition, and nutrient availability within aquatic ecosystems (Colombo et al., 2017).

The second major SFA component identified in both fish oils was stearic acid (C18:0), accounting for 11.76% in Siro fish oil and 10.02% in Tembang fish oil. Myristic acid (C14:0) also showed marked variation between the two species, with concentrations of 6.18% in Siro fish and 11.78% in Tembang fish. These differences may be associated with species-specific lipid metabolism and variations in natural dietary sources (Glencross et al., 2020). Several minor saturated fatty acids, including lauric acid (C12:0), arachidic acid (C20:0), heneicosanoic acid (C21:0), and behenic acid (C22:0), were also detected at relatively low concentrations (<1%). Although present in small amounts, these saturated fatty acids may still contribute to the oxidative stability of fish oil because the lower degree of unsaturation in SFAs makes them more resistant to oxidative degradation than PUFAs (Demets et al., 2022).

Overall, Siro fish oil (*Amblygaster sirm*) and Tembang fish oil (*Sardinella fimbriata*) exhibited DHA as the predominant PUFA component and palmitic acid as the major SFA component. This profile indicates that both species possess considerable potential as DHA-rich fish oil sources that could be further developed as raw materials for functional foods and nutraceutical products derived from local fisheries resources.

Conclusion

This study successfully characterized and established baseline data on the fatty acid profiles of fish oils derived from two dominant small pelagic fish species from West Sumbawa, namely *Amblygaster sirm* (siro) and *Sardinella fimbriata* (tembang). The results demonstrated that both species possess valuable functional lipid characteristics, particularly a high concentration of docosahexaenoic acid (DHA), which accounted for more than 20% of the total fatty acid composition. Although the tropical aquatic environment may contribute to relatively low baseline levels of eicosapentaenoic acid (EPA), the substantial accumulation of DHA and arachidonic acid (ARA) highlights the potential of these local fish resources as promising sources of DHA-rich fish oil for nutritional and functional applications. Furthermore, the predominance of palmitic acid and stearic acid indicates that saturated fatty acids constitute an important structural component of the lipid profiles of both species.

From an industrial perspective, the favorable fatty acid composition of these fish oils presents considerable potential for commercial utilization, particularly in the development of functional food ingredients and high-value nutraceutical products. To fully realize this potential, future studies should focus on evaluating the oxidative stability of the extracted fish oils during storage and processing, as well as investigating their specific biological activities through in vivo assessments. Such investigations are essential for ensuring product quality, extending shelf life, and substantiating the associated health benefits for consumer applications.

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Author Contributions

B.P.H.: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – Original Draft, Project administration, Resources, Funding acquisition; B.A.L.F.: Methodology, Investigation, Data curation, Writing – Original Draft, Visualization; Y.L.V.A.: Validation, Writing – Review & Editing, Visualization, Supervision.

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Conflicts of Interest

The authors declare no conflict of interest.

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