Nigerian Journal of Fisheries Vol. 22, No. 2; 2025

EVALUATION OF FATTY ACID PROFILE OF FISH OIL SELECTED FROM SOME FISH SPECIES AT HADEJIA FISH MARKET

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ABSTRACT

The study investigated the nutritional properties of oils extracted from three freshwater fish species (Mormyrus rume, Bagrus bayad and Heterotis niloticus) collected from Hadejia Fresh Fish Market, Jigawa State, Nigeria. Fish oils were extracted using the Soxhlet method following AOAC procedures. The extracted oils were analyzed for fatty acid composition using Gas chromatography following standard experimental procedure and data were statistically evaluated through one-way ANOVA at a significance level of p<0.05.Results revealed significant interspecific variation (p<0.05) in oil. The fatty acid profiles demonstrated significant differences among species,with Heterotis niloticus showing higher levels of palmitic, oleic, cis-vaccenic, and n-hexadecanoic acids, whereas Bagrus bayad contained the highest levels of squalene, eicosane, and other hydrocarbons. Cholesterol was detected only in Momyrus rume. The observed differences suggest species-specific lipid metabolism and ecological adaptation influencing fatty acid composition. Oils from Heterotis niloticus and Bagrus bayad exhibited favorable 9-octadeceoic acid, palmitoleic and octadecanoic acids profiles, highlighting their nutritional potential for human consumption and industrial application

Keywords: Freshwater fish, Oil, Fatty acid, Fish Market

INTRODUCTION

Fish oil is widely recognized as one of the richest natural sources of omega-3 polyunsaturated fatty acids (PUFAs), especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids contribute to numerous physiological and therapeutic functions including cardiovascular protection, anti-inflammatory responses, immune enhancement, neural development, vision improvement, and prevention of metabolic disorders (Anas, 2020; Pateiro , 2021; Sarter , 2023). Growing awareness about these health benefits has driven a surge in global demand for fish oil and omega-3 supplements (Anas , 2020; Mozaffarian and Wu, 2022).

Fish also plays a vital nutritional role in developing countries such as Nigeria. Studies by Ayeloja et al. (2023), Roopma, (2012), and Begum and Minar (2012) emphasized fish as a highly digestible source of essential amino acids, high-quality proteins, vitamins, minerals, and PUFAs. Because of these attributes, fish significantly contributes to food and nutrition security, particularly for low-income populations.

Fish oil differs from vegetable and other animal oils due to its higher content of long-chain unsaturated fatty acids, which make it chemically unique (Bako, 2017). This includes substantial levels of EPA and DHA, which are necessary for proper physiological functioning (Abdulkadir *et al.,* 2010; Nazir, 2017). Fish oil is also associated with managing ulcers, cataracts, kidney dysfunctions, diabetes, inflammatory complications, and mental health problems (Nazir, 2017; Jeyanathan, 2022).

Fish oils are chemically diverse, containing PUFAs (EPA, DHA, arachidonic acid), monounsaturated fatty acids (oleic acid, palmitoleic acid), saturated fatty acids (palmitic acid, stearic acid), sterols, carotenoids, polyphenols, vitamins, and trace minerals (Straight, 2020; Ashraf, 2020; Yildiz, 2022). These components contribute to their nutritional and industrial significance. Despite the economic and nutritional relevance of fish oils, limited scientific information exists regarding the nutritional qualities of oils derived from tropical freshwater species commonly marketed in Hadejia, including *Mormyrus rume, Bagrus bayad,* and *Heterotis niloticus*. The fatty acid compositions and potential contaminants (e.g., hydrocarbons, phthalates) have not been adequately investigated. This lack of documented data hinders effective utilization of these fish species for oil production and may limit opportunities for value addition, consumer health benefits, and income generation for local processors and vendors. The need to address these knowledge gaps motivates the present study. This study will generate valuable scientific information on the suitability of selected tropical freshwater fish species as sources of high-quality fish oil. Evaluating their nutritional characteristics will support improved processing, storage, and utilization of locally available species. EPA and DHA have been linked to improved cardiovascular function, neural development, reduced inflammation, enhancement of immunity, and improvement in metabolic health (Pateiro, 2021; Sarter, 2023).

Fish oil is therefore widely employed in pharmaceuticals, food fortification, and supplement industries. More than one million tons of fish oil are produced globally each year, mainly from marine by-products (FAO, 2022).By evaluating the quality of oils from *Momyrus rume, Bagrus bayad,* and *Heterotis niloticus*, this research contributes to the sustainable utilization of aquatic resources and supports local economic development. The study aims to characterize fish oils extracted from *Mormyrus rume*, *Bagrus bayad*, and *Heterotis niloticus* and assess the fatty acid profile, hydrocarbon content, and phthalate composition of the oils. This study focuses on three freshwater fish species (*Mormyrus rume*, *Bagrus bayad*, and *Heterotis niloticus*) sourced from Hadejia Fresh Fish Market. It examines their nutritional (fatty acid profile, hydrocarbons, phthalates) properties.

RESEARCH METHODOLOGY

Study Area

The study was conducted in the laboratory of the Department of Fisheries and Aquaculture, Faculty of Agriculture, Federal University Dutse, Jigawa State, Nigeria (latitude 11° 42′ N, longitude 9° 22′ E; elevation ~ 436 m above sea level).

Experimental Fish

Fresh samples, three kilogram each of *Mormyrus rume*, *Bagrus bayad*, and *Heterotis niloticus* were procured from Hadejia fresh fish market in Jigawa State, Nigeria. For lipid extraction and analysis, high-purity gases and solvents were used: commercial liquefied CO_2 (≥ 99.9 %), nitrogen (carrier gas, ≥ 99.9 %), hydrogen (auxiliary gas, ≥ 99.9 %), and compressed air (free from organic impurities) were purchased. Petroleum ether and n-hexane were also obtained for sample treatment and extraction.

Collection, Transportation, and Sample Preparation

Three kilograms of each fish species were collected and immediately transported to the laboratory in insulated polypropylene woven containers, maintained in a frozen state. Upon arrival, each species' sample was divided into three, 1 kg portions, labeled, and stored at −20 °C until further analysis.

Prior to analysis, samples were thawed, homogenized, and a representative aliquot was taken for Soxhlet extraction. The extracted lipids were stored under inert atmosphere (nitrogen) at −20 °C to prevent oxidation until nutritional assessment. The nutritional evaluation (e.g., fatty acid profiling) was performed at the Biochemistry Department, Faculty of Clinical Sciences, Ahmadu Bello University, Zaria.

Fish Oil Extraction by Soxhlet Method

Lipid extraction was carried out following a modified version of the AOAC Soxhlet method (as commonly used in fish oil studies). A 250 ml round-bottom flask was dried at 105–110 °C for 30 minutes, cooled in a desiccator, and weighed. Approximately 2 g of homogenized fish tissue was placed in a cellulose thimble, lightly packed with cotton wool, and inserted into the Soxhlet apparatus. Petroleum ether (about 300 ml, b.p. ~ 60 °C) was used as the extraction solvent. The system was refluxed for approximately 6 hours. After extraction, the solvent was recovered, and the flask was evaporated to dryness in an oven at 105 °C for 1 hour, cooled in a desiccator, and weighed and calculated as follow

$$\% \text{Fat} = \frac{w_1}{W_2} \times 100$$

Where w_1=weight of the Fat (g)
W_2=weight of the sample (g)

Gas Chromatography (GC) Analysis of Fatty Acids

For fatty acid profiling, 50–150 mg of extracted oil was placed into a screw-cap reaction vial along with an internal standard (e.g., 200 µg). A mixture of 1.5 ml methanol and 0.2 ml toluene was added, followed by 0.3 ml of 8% HCl in methanol. The vial was heated to 80 °C for 1 hour to methylate the fatty acids, and then cooled. After cooling, 1 ml of water and 1 ml of hexane were added, vortexed, and centrifuged. The upper (hexane) layer containing the fatty acid methyl esters (FAMEs) was collected, dried over anhydrous sodium sulfate, filtered, concentrated under a gentle stream of nitrogen to ~0.5 ml and transferred to a GC vial for analysis.

Statistical Analysis

All data generated from the nutritional assessments were subjected to statistical analysis. A one-way analysis of variance (ANOVA) was conducted at a 95% confidence level ($p < 0.05$) to test for significant differences between species. Means were compared using Duncan's Multiple Range Test (DMRT) via SPSS version 16.0.

RESULTS

Fatty Acid Composition of the Extracted Fish Oil

Table 1 presents the fatty acid (FA) composition of oils from *M. rume, H. niloticus* and *B. bayad*, and reveals significant differences ($p < 0.05$) among compounds for each species. Notably:*M. rume* recorded the highest value for tetradecanoic acid (98.00 ± 1.41) and the lowest palmitoleic acid (35.00 ± 7.07).*B. bayad* showed the highest palmitoleic acid (97.50 ± 2.12).*H. niloticus* had highest palmitic acid (53.50 ± 7.77) and oleic acid (59.00 ± 1.41) while *M. rume* recorded the least for these.*H. niloticus* also recorded the highest values for cis-vaccenic acid (65.00 ± 15.55), n-hexadecanoic acid (91.50 ± 2.12),linoelaidic acid (92.00 ± 141) and lowest tetradecanoic acid value (97.00 ±1.32) while *M. rume* had the least for 9-octadecanoic acid (87.50 ± 16.26) and octadecanoic acid (54.00 ± 15.55).*B. bayad* exhibited the highest in 9-octadecanoic acid (98.50 ± 9.02) and octadecanoic acid (95.50 ± 2.12).

Table 1: Fatty acids compositions and analysis of fish oil

Compounds	Momyrus rume	Heterotis niloticus	Bagrus bayad
tetradecanoic acid	98.00±1.41[a]	97.00±1.32[c]	97.50±0.70[b]
palmitoleic acid	35.00±7.07[c]	96.50±3.53[b]	97.50±2.12[a]
palmitic acid	35.00±7.07[c]	53.50±7.77[a]	53.00±5.65[b]
oleic acid	46.50±12.02[c]	59.00±1.41[a]	47.50±3.53[b]
cis-vaccenic acid	52.50±10.60[c]	65.00±15.55[a]	62.50±3.53[b]
n-hexadecanoicacid	75.00±7.07[b]	91.50±2.12[a]	69.00±1.41[c]
9-octadeceoic acid	87.50±16.26[c]	97.00±0.00[b]	98.50±9.02[a]
octadecanoic acid	54.00±15.55[c]	58.50±0.70[b]	95.50±2.12[a]
Pentadecanoic	52.50±10.60[b]	71.50±30.40[a]	51.50±2.12[c]

KEY: a,b,c= Avarage values on the same row with different superscript differs significantly ($p<0.05$) **.**

Hydrocarbon Composition of the Extracted Fish Oil

As shown in Table 2, hydrocarbons in the fish oils varied significantly ($p < 0.05$). *H. niloticus* recorded the highest hexadecane (95.50 ± 3.53) while *M. rume* had the lowest (58.00 ± 2.82). *B. bayad* exhibited the highest eicosane (86.00 ± 8.48), heptadecane (93.50 ± 8.48), octadecane (90.50 ± 4.49) and 1-octadecene (91.50 ± 10.60), whereas *M. rume* had the lowest values for those compounds.

Table 2: Hydrocarbons compositions and analysis of fish oil

Compounds	Momyrus rume	Heterotis niloticus	Bagrus bayad
Tetradecane	72.50±20.50[c]	75.00±21.21[b]	88.50±2.12[a]
Pentadecane	57.50±17.67[c]	74.00±5.65[b]	79.00±4.24[a]
Hexadecane	58.00±2.82[c]	95.50±3.53[a]	61.50±9.19[b]
Eicosane	47.50±3.53[c]	65.00±21.21[b]	86.00±8.48[a]
Heptadecane	91.50=2.12[b]	88.00±12.72[c]	93.50±8.48[a]
Octadecane	81.00±19.97[c]	87.00±12.72[b]	90.50±4.95[a]
1-octadecene	53.00±4.24[c]	83.50±20.50[b]	91.50±10.60[a]

KEY: a,b,c= Avarage values on the same row with different superscript differs significantly ($p<0.05$).

Phthalates, Squalene and Cholesterol Composition of the Extracted Fish Oil

From Table 3, *B. bayad* recorded the highest value for bis(2-ethylhexyl) phthalate (80.00 ± 2.82) while *M. rume* had the lowest (58.00 ± 2.32). *M. rume* recorded the highest values for dibutyl phthalate (80.00 ± 14.14) and diisoctyl phthalate (80.00 ± 14.14), while *B. bayad* recorded the lowest for those compounds (16.00 ± 29.0 and 51.00 ± 2.8 respectively). *B. bayad* had the highest squalene (98.50 ± 0.70) while *M. rume* had the lowest (80.50 ± 16.26). Cholesterol was only detected in *M. rume* (96.50 ± 3.53) and was absent (0.0000) in the other two species.

Table 3: phthalates, squalene and cholesterol compositions and analysis of fish oil

Compounds	Momyrus rume	*Heterotis niloticus*	Bagrus bayad
(bis(2-ethylhexyl)	58.00±2.32[c]	68.00±11.31[b]	80.00±2.82[a]
Dibutyl	80.00±14.14[a]	55.50±34.64[b]	29.00±8.48[c]
Diisocty	80.00±14.14[a]	50.00±28.90[b]	16.00±29.0[c]
di-n-octyl	64.00±11.31[b]	65.50±2.12[a]	51.00±2.82[c]
Squalene	80.50±16.26[c]	87.50±16.26[b]	98.50±0.7[a]
Cholesteral	96.50±3.53[a]	0.00000000	0.0000000

KEY: a,b,c= Avarage values on the same row with different superscript differs significantly ($p<0.05$).

DISCUSSION

The results of this study indicate that the oils extracted from *M. rume, H. niloticus* and *B. bayad* differ significantly ($p < 0.05$) across almost all fatty acid, hydrocarbon and minor compound parameters. These interspecific differences are consistent with the broader literature which attributes variation in oil composition to species-specific lipid metabolism, ecological niche, diet, and environmental/seasonal conditions (Ngamga, 2024; Ayeloja, 2024).

The analysis of Fatty Acid profiles (Table 1) demonstrates that *M. rume*, *H. niloticus,* and *B. bayad* exhibit distinct Fatty Acid signatures. The observed high tetradecanoic acid content in *M. rume* compared to the other species is noteworthy, while it presented the lowest value for palmitoleic acid. This indicates variations in the de novo fatty acid synthesis or selective accumulation of specific fatty acids in *M. rume*. Conversely, *B. bayad* exhibited the highest palmitoleic acid content and the lowest tetradecanoic acid content. These observations suggest that these species may have different metabolic strategies in handling and storing these specific fatty acids, potentially linked to differences in their membrane fluidity or energy storage (Arts *et al.,* 2009). Palmitoleic acid, in particular, has been linked to various health benefits in humans (Guil-Guerrero *et al.,* 2000).

H. niloticus showed the highest levels of palmitic acid and oleic acid, indicating a potential for increased saturated and monounsaturated fatty acid content in this species. Further, the higher levels of cis-vaccenic acid, n-hexadecanoic acid, and linoelaidic acid, observed in *H. niloticus,* might suggest different physiological roles, such as enhanced membrane stability or adaptability to environmental stressors (Hazel, 1995). The result shows that palmitic (C16:0), oleic (C18:1) and related fatty acids dominated is consistent with recent studies of African freshwater fish (Funmilayo et al., 2024) and the general pattern in freshwater species of higher monounsaturated fatty acids but lower long-chain n-3 PUFA (Khan , 2024). In the words of Mahindarathna et al. (2024): "freshwater fish exhibit a broader distribution of fatty acids, particularly among various long-chain polyunsaturated acids". Specifically, It was observed that *H. niloticus* had the highest oleic acid which is relevant because oleic acid (C18:1) has been widely reported as the predominant monounsaturated fatty acid in African freshwater species and is linked to cardiovascular benefit (Funmilayo, 2024) which was in agreement with the findings, of Ayeloja (2024) which emphasizes that "oil extracted from freshwater fish species shows significant variation in fatty acid composition due to species, habitat, diet and seasonal factors."

In contrast, the lower values of 9-octadecanoic acid and octadecanoic acid in *M. rume* could be interpreted in the context of the fish's environment and feeding habits. *B. bayad,* on the other hand, exhibited high levels of 9-octadecanoic acid and octadecanoic acid, possibly indicative of a different source of dietary fats or unique metabolic processing compared to the other species (Tocher, 2003).

Similarly, palmitoleic acid (C16:1) is increasingly noted for its metabolic significance (e.g., insulin sensitivit) and from the results that *B. bayad* had elevated palmitoleic acid support its nutritional potential. The dominance of C16 and C18 fatty acids (palmitic, palmitoleic, oleic, vaccenic acids) in the samples aligns with global freshwater fish oil profiles where long chain polyunsaturated fatty acids (e.g., EPA, DHA) are often lower compared to marine species (Khan, 2024) .

The differences recorded likely reflect species-specific lipid metabolism and ecological roles: e.g., *H. niloticus* is omnivorous/detritivorous, favouring monounsaturated fatty acids precursors, whereas *M. rume* may have a different tropic niche and diet leading to lower monounsaturated fatty acids levels.

From a nutritional viewpoint, oils extracted are rich in monounsaturated fatty acids but likely lower in long-chain n-3 polyunsaturated fatty acids (EPA, DHA) given the typical profile of freshwater species (Mahindarathna et al., 2024). In aquaculture and industrial terms, identification of species (like *H. niloticus and B. bayad*) with favorable monounsaturated fatty acids profiles invites opportunities for feed manipulation to enhance health beneficial fatty acid content (Ngamga, 2024)

Hydrocarbons in fish oils are less commonly reported, but they may originate from neutral lipid storage or be derived from metabolic by-products or environmental contaminants (Gonçalves, 2020).

The hydrocarbon profiles (Table 2) further differentiated the three species. The higher hexadecane content in *H. niloticus,* while the lowest value was in *M. rume ,* could influence the oxidative stability and sensory characteristics of the oil. The high levels of eicosane, heptadecane, octadecane, and 1-octadecene in *B. bayad* further suggest unique biochemical pathways and variations in the synthesis and/or incorporation of these hydrocarbons within the fish. These hydrocarbon variations may play roles in membrane structure, buoyancy control, or serve as energy reserves (Sushchik *et al.,* 2006). The differences in hydrocarbon content might also indicate variations in the fish's ability to cope with environmental stressors or dietary toxins.

The high squalene in *B. bayad* is noteworthy, since squalene is a triterpenoid with antioxidant and nutraceutical value. Literature highlights fish oils as sources of squalene for pharmaceutical and cosmetic uses (Popa, 2020). While phthalate (in terms of oil quality and safety) is less common in freshwater fish oils, these results suggest species-specific accumulation, measurement and potential purification needs. The unexpected absence of detectable cholesterol in *H. niloticus* and *B. bayad* raises analytical questions (e.g., extraction efficiency, sterol co-elution (Nava, 2023). From a human nutrition perspective, the higher monounsaturated fatty acids (oleic, palmitoleic) content in *H. niloticus* and *B. bayad* is beneficial: oleic acid is associated with improved lipid profiles and reduced cardiovascular risk (Funmilayo, 2024). However, as freshwater fish generally have lower EPA/DHA levels than marine species, this should be factored into dietary suggestions (Khan, 2024).

From an aquaculture/industrial viewpoint, species with favorable monounsaturated fatty acids/squalene profiles (e.g., *H. niloticus* and *B. bayad*) may be targeted for feed manipulation or selective breeding to further enhance these traits (Ngamga, 2024).

The fatty acid (FA) and hydrocarbon profiles of fish oils extracted from *M. rume, H. niloticus*, and B. bayad reveal significant interspecies variations, highlighting the influence of species-specific metabolic pathways and dietary habits on oil composition. These differences ($p < 0.05$) are crucial, as Fatty Acid and hydrocarbon compositions directly impact the nutritional and potential industrial applications of these fish oils. These variations are often linked to factors such as diet, habitat, and species-specific metabolic capabilities (Sargent *et al.,* 1999).

The observed variations in Fatty Acid and hydrocarbon compositions have significant implications. The Fatty Acid profiles affect the nutritional quality of the oil. For instance, the presence of specific unsaturated fatty acids may influence the oil's suitability for human consumption or animal feed. Hydrocarbons play a crucial role in lipid stability and could impact shelf-life (Frankel, 2005). The balance between saturated and unsaturated fatty acids is a key determinant of oil quality and potential health benefits (Kris-Etherton *et al.,* 2002).

CONCLUSION

The study underscores significant interspecific differences in fatty acid and hydrocarbon profiles. *H. niloticus* and *B. bayad* are rich in oleic and palmitoleic acids, important for cardiovascular and metabolic health, while *B. bayad* also provides a notable source of squalene, a bioactive compound with antioxidant and therapeutic potential. These interspecific differences reflect species-specific dietary inputs, lipid metabolism, and lipid class distribution. The study highlights the significant differences in Fatty Acids and hydrocarbon compositions among the three fish species. The fatty acid (FA) and hydrocarbon profiles of fish oils extracted from *M. rume, H. niloticus*, and *B. bayad* reveal significant interspecies variations, highlighting the influence of species-specific metabolic pathways and dietary habits on oil composition. These differences are crucial, as fatty acid and hydrocarbon compositions directly impact the nutritional and potential industrial applications of these fish oils. These variations are often linked to factors such as diet, habitat, and species-specific metabolic capabilities. The observed variations in fatty acid and hydrocarbon compositions have significant implications. The fatty acid profiles affect the nutritional quality of the oil. For instance, the presence of specific unsaturated fatty acids may influence the oil's suitability for human consumption or animal feed. Hydrocarbons play a crucial role in lipid stability and could impact shelf-life. The balance between saturated and unsaturated fatty acids is a key determinant of oil quality and potential health benefits.

RECOMMENDATIONS

Based on the outcomes of this study, the following recommendations were made:

- The high levels of omega-3 fatty acids, particularly palmitoleic and oleic acids, indicate that these fish oils can be developed as nutritional supplements to support human health..
- Detection of contaminants such as phthalates in some samples underscores the necessity of implementing rigorous quality control and safety measures in fish oil at Hadejia Fish Market.

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CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

AUTHOR'S CONTRIBUTIONS

Y. Chiroma managed the research designed, procuring, preparation of the sample for laboratory analysis, data collection, preparation, analysis and writing the manuscript. M. A Haruna and I. Y Idoke supervise the work. All authors read and approved the final manuscripts.