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The importance of African catfish (*Clarias gariepinus*) in functional foods and nutraceutical

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Abstract

The relationship between diet and health has garnered significant attention, with increasing interest in foods that support disease prevention and overall well-being. This study highlights the functional role of African catfish (*Clarias gariepinus*) in human nutrition and health, specifically examining its potential as a functional food and nutraceutical. As a vital component of food security, fish offers essential nutrients beyond basic nutrition, including omega-3 fatty acids and bioavailable micronutrients. This review combines secondary data and insights from fish utilization experiences to outline catfish's functionality and health-promoting properties. It explores previous studies on the nutritional profile, fatty acid composition, and health advantages of catfish as well as studies on fish's role in food security and functional foods. Practical observations and empirical research further informed the bioavailability and efficacy of key nutrients in catfish. This combined approach allowed a thorough assessment of the nutraceutical potential of both cage-cultured and wild catfish, highlighting its value in promoting health and preventing chronic diseases. Analysis of fatty acid profiles in both cage-cultured and wild-caught catfish reveals that catfish provides a balanced array of fatty acids, with cage-cultured samples containing 33.19% saturated fatty acids (SFA), 51.47% monounsaturated fatty acids (MUFA) and 15.35% polyunsaturated fatty acids (PUFA), including essential omega-3 eicosapentaenoic (EPA) and docosahexaenoic acids (DHA), which are linked to cardiovascular health benefits. This profile underscores catfish's potential as a functional food to improve dietary quality and support disease prevention. The study contributes valuable insights for both consumers and policymakers on the importance of catfish in achieving healthy diets.

Introduction

Catfish (*Clarias gariepinus*), a widely farmed species across Africa and other parts of the world, has gained considerable attention in nutrition science for its potential as a functional food and nutraceutical. Functional foods are defined as those that provide health benefits beyond basic nutrition, contributing positively to disease prevention and overall well-being (Shahidi and Ambigaipalan, 2015). As a functional food, catfish delivers essential nutrients like high-quality proteins, healthy fats, and various micronutrients that enhance physiological functions and help mitigate health risks particularly in relation to cardiovascular diseases, inflammation, and metabolic health (Kris-Etherton *et al*., 2002; Milićević *et al*., 2017). Fish is particularly valued for its high protein content and balanced amino acid profile, making it a crucial source of protein in many regions with limited access to diverse protein sources (Adeyemi *et al*., 2013). Fish is also rich in essential fatty acids, particularly omega-3 polyunsaturated fatty acids (PUFAs) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), known for their anti-inflammatory properties and beneficial effects on cardiovascular health (Nettleton and Katz, 2005). In a study comparing cultured and wild *C. gariepinus*, the fatty acid profile indicated significant levels of omega-3 fatty acids, with cage-cultured catfish showing 15.35% PUFAs, showing potential for addressing nutrient deficiencies and supporting cardiovascular health (Ayeloja *et al*., 2019). These fatty acids contribute to the reduction of

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Low Density Lipids (lLDL) cholesterol and triglycerides, improving lipid profiles and reducing the risk of atherosclerosis and related cardiovascular diseases (Mozaffarian and Wu, 2011).

In addition to its nutrient density, the bioavailability of nutrients in catfish is another key factor contributing to its functional food status. The high bioavailability of nutrients such as omega-3 fatty acids, zinc, selenium, and vitamin D in catfish allows for efficient absorption and utilization by the human body, thereby promoting immune function, bone health, and reducing inflammation (Marquez *et al*., 2012; Osterholt *et al*., 2015). Studies have highlighted the role of fish as a reliable source of these bioavailable micronutrients, which are often deficient in low-income regions, contributing to malnutrition and compromised immunity (Golden *et al*., 2016).

Catfish can also be considered a nutraceutical, as its consumption can play a therapeutic role in managing and preventing various diseases. Nutraceuticals are food products that provide health benefits beyond their basic nutritional value, often in a medicinal or therapeutic context (Kalra, 2003). The regular inclusion of catfish in the diet has shown promising effects in reducing blood pressure, supporting cognitive health, and managing inflammatory responses due to the anti-inflammatory and lipid-regulating properties of omega-3 fatty acids (Golden *et al*., 2016). Furthermore, studies have suggested that the antioxidants found in fish, such as selenium, may contribute to oxidative stress reduction, providing additional support against chronic diseases like cancer and type 2 diabetes (Raatz *et al*., 2013).

The rising global prevalence of chronic diseases, including cardiovascular diseases, diabetes, and obesity, has heightened the demand for foods that offer health benefits beyond basic nutrition (Kris-Etherton *et al*., 2002). In developing regions, nutritional deficiencies remain a critical issue, with many populations lacking access to high-quality protein and essential micronutrients (Golden *et al*., 2016). As a dietary staple in many parts of the world, fish holds immense potential as a functional food, providing bioavailable nutrients such as omega-3 fatty acids, essential amino acids, and minerals like selenium and zinc (Raatz *et al*., 2013).

African catfish is an affordable and readily available protein source, especially in low-income regions, making it a strategic food choice for addressing malnutrition and health challenges. Yet, empirical data on its functional and nutraceutical benefits, particularly the differences in fatty acid profiles between wild-caught and cultured varieties, is limited. Understanding these differences is critical to optimizing its use in improving health outcomes and preventing diet-related diseases. Furthermore, there is a need to provide robust scientific evidence to inform dietary recommendations and policy-making on incorporating catfish into functional food frameworks.

Fish is recognized globally as a nutrient-dense food, particularly for its content of high-quality protein, omega-3 fatty acids, and essential micronutrients (Shahidi and Ambigaipalan, 2015). Omega-3 fatty acids, such as EPA and DHA, are crucial for cardiovascular health, cognitive function, and reducing inflammation, making fish an essential component of a functional diet (Mozaffarian and Wu, 2011). In many African countries, including Nigeria, African catfish is a primary source of animal protein due to its affordability, availability, and adaptability to aquaculture (Adeyemi *et al*., 2013). Understanding the functional and nutraceutical benefits of this species is particularly relevant for improving public health in regions where access to diverse food sources is limited.

While studies have explored the general nutritional benefits of fish, the specific fatty acid profiles and functional properties of African catfish, particularly the differences between wild-caught and cultured varieties, are not well-documented (Ayeloja *et al*., 2019). This study aims to fill this gap by providing empirical evidence on the health-promoting properties of African catfish, supporting its classification as a functional food andnutraceutical.

Findings from this study will inform food security strategies and dietary guidelines, particularly in addressing malnutrition and diet-related health issues. Policymakers can leverage the results to promote the production and consumption of African catfish as a cost-effective functional food source.

With its robust nutritional profile, bioavailable micronutrients, and beneficial fatty acid composition, catfish stands out as both a functional food and nutraceutical that can support human health and contribute to disease prevention. Its unique nutrient composition highlights the value of incorporating *C. gariepinus* into diets, especially in regions where malnutrition and chronic disease rates are high, underscoring its role in food security and public health.

This study was carried out to evaluate the potential of African catfish as a functional food and nutraceutical, by analyzing its nutritional and health-promoting properties, with a focus on its fatty acid composition.

Materials and Methods

This study used an empirical approach to evaluate the fatty acid profile of African catfish sourced from both wild and cultured environments, alongside a review of literature to establish its functionality as a food and nutraceutical. The research was conducted in two main phases: data collection and laboratory analysis, followed by comparative evaluation of fatty acid composition.

Collection of Samples: table- sized catfish samples were obtained from two distinct environments- Epe and Ise fishing communities in Epe and Ibeju Lekki Local Government areas of Lagos State respectively. Wild-caught samples were collected from Epe lagoon, while cage-cultured samples were obtained from Lekki Lagoon at the Ise fishing community (one of the Fish Cage Demonstration sites of the Federal College of Fisheries and Marine Technology). Twenty-five (25) pieces each of averagely sized (500g) freshly harvested *C. gariepinus* were collected from the two locations. All samples were selected based on similar weight and maturity levels to minimize variables that could influence fatty acid composition, following the sampling methods of Adeyemi *et al*. (2013) and Ayeloja *et al*. (2019). The samples were immediately stored on ice to preserve freshness and transported to the laboratory for analysis.

Preparation of Samples: The muscle tissue of the fish was homogenized using a blender to ensure uniformity (Marquez *et al*., 2012). The homogenized samples were freeze-dried to prevent oxidation of lipids (Osterholt *et al*., 2015). Lipids were extracted from the muscle tissue using the Bligh and Dyer method (Bligh and Dyer, 1959). A mixture of methanol, chloroform, and *water* was used to separate lipids from the fish muscle. Extracted lipids were then separated into a chloroform layer, which was used for further analysis.

To prepare the fatty acids for gas chromatography (GC) analysis, the extracted lipids were methylated to form fatty acid methyl esters (FAMEs), following the method described by Christie (2003). Methylation was achieved by adding methanolic HCl to the lipid extracts and heating the mixture at 60°C for one hour. After cooling, FAMEs were separated, washed, and dried under nitrogen gas to prevent oxidation. FAMEs were analyzed using gas chromatography (GC) with flame ionization detection (GC-FID), which allows for accurate quantification of individual fatty acids (Christie, 2003). A 1 µL of each FAME sample was injected into the GC system equipped with a capillary column. Initial oven temperature was set to 50°C, then increased at a rate of 4°C per minute until it reached 220°C, ensuring optimal separation of FAMEs. Fatty acids were identified by comparing retention times with those of known standards. The main fatty acids of interest included omega-3 and omega-6 PUFAs, SFAs, and MUFAs, in alignment with methods by Mozaffarian and Wu (2011) and Raatz *et al*. (2013).

The results from GC analysis provided quantitative values for each fatty acid. Statistical analysis was performed using ANOVA to determine significant differences in fatty acid composition between the wild and the cultured samples. The Saturated Fatty Acids (SFA), Monounsaturated Fatty Acids (MUFA), Polyunsaturated Fatty Acids (PUFA) and Omega-3 and Omega-6 Ratios were compared.

Results were discussed in the context of health benefits associated with each fatty acid type, following studies such as Kris-Etherton *et al*. (2002), which emphasize the importance of omega-3 PUFAs for cardiovascular health. This analysis helped to determine the nutraceutical potential of each fish group, as cultured fish often exhibit higher PUFA levels due to controlled feeding regimens, while wild fish may offer a broader range of naturally occurring nutrients (Ayeloja *et al*., 2019).

In addition to empirical analysis, a systematic review of existing literature on functional foods and fish nutraceuticals was conducted. Relevant academic articles on the nutritional benefits, bioavailability of micronutrients, and therapeutic roles of catfish were reviewed to contextualize the empirical findings. Key references included works on fish as a functional food (Shahidi and Ambigaipalan, 2015) and studies detailing nutrient bioavailability (Golden *et al*., 2016).

Finally, results from both empirical and literature-based analyses were synthesized to highlight the role of *C. gariepinus* as a functional food and nutraceutical. Differences in omega-3 fatty acid levels, SFA, and PUFA content between wild and cultured fish were discussed in relation to their health implications. Based on the findings, practical recommendations for incorporating catfish into diets were suggested, especially in contexts with limited access to diverse sources of omega-3 fatty acids and high-quality protein.

Results and Discussion

The findings align with broader research emphasizing how environmental and dietary factors influence the biochemical composition of fish (Rückert *et al*., 2019).

Saturated Fatty Acids (SFA)

Stearic acid (C18:0) was the predominant SFA in both wild and cage-cultured fish, with levels of 17.06% and 28.82%**,** respectively. Cage-cultured fish also showed a higher overall SFA content **(**33.22%**)** than wild-captured samples **(**22.48%**).** These differences may stem from the controlled feeding regimens in aquaculture, which often include lipid-rich feed to enhance growth and fat deposition (Izquierdo *et al*., 2003).

Palmitic acid (C16:0), another major SFA, was more prevalent in wild fish **(**4.83%**)** than in cultured ones **(**0.85%**),** a trend reported in studies comparing wild and farmed species due to the quality of feed they are fed (Turchini *et al*., 2009). The absence of pentadecanoic acid (C15:0) and myristic acid (C14:0) in cultured samples further highlights the dietary dependency of fatty acid synthesis in fish.

Monounsaturated Fatty Acids (MUFA)

Wild fish exhibited a significantly higher MUFA content (**72.21%**) compared to cage-cultured samples (**48.26%**), with cis-10-heptadecanoic acid (C17:1) as the predominant MUFA in both groups. Elevated MUFA levels in wild fish are consistent with findings from studies on species subjected to natural feeding habits, where plant and algae-based diets rich in MUFA dominate (Sargent *et al*., 2002).

Polyunsaturated Fatty Acids (PUFA)

PUFAs, especially omega-3 fatty acids like eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), were significantly higher in cage-cultured fish (**16.19%**) than in wild fish **(**4.94%**).** The absence of EPA and linolenic acid (C18:3) in wild samples but their presence at 4.76% and 2.36% in cultured samples aligns with prior research linking PUFA levels to aquaculture feed formulations enriched with fish oil or plant-based omega-3 sources (Bell *et al*., 2004).

DHA levels were 3.20% in cultured fish compared to 1.41% in wild specimens. DHA, a crucial omega-3 fatty acid, supports cardiovascular health, neural development, and cell membrane integrity (Calder, 2020). These findings reflect studies by Kris-Etherton *et al*. (2002), who identified DHA as a key factor in reducing the risk of cardiovascular diseases and promoting cognitive health. All these are shown in figure 2 above.

Omega-3 Fatty Acids and Nutritional Implications

Omega-3 fatty acids, estimated at 10.32% in cultured samples and 2.81% in wild fish, demonstrate the enhanced nutritional value of cage-cultured *C. gariepinus***.** These levels surpass findings in other freshwater species like Nile tilapia (*Oreochromis niloticus*) in aquaculture systems. The results also align with dietary recommendations of at least 1 g/day of combined EPA and DHA intake for optimal human health (FAO/WHO, 2010). Studies by Turchini *et al*. (2009) consistently highlight that fatty acid profiles in farmed fish are closely linked to the composition of aquafeeds, which are often tailored to improve omega-3 content. Wild fish fatty acid composition varies due to factors like prey availability, habitat type, and water temperature, as reported in Rückert *et al*. (2019). Research by Shahidi and Ambigaipalan (2015) underscores DHA and EPA's role in reducing inflammation, improving heart health and supporting brain development.

The results suggest that cultured *C. gariepinus* offers enhanced nutritional benefits due to its higher PUFA. While wild fish exhibited higher MUFA, the significant increase in omega-3 levels in cultured fish underscores its potential as a functional food for improving cardiovascular and cognitive health.

The findings as shown in figures 1 and 2 are consistent with prior studies emphasizing the influence of aquaculture practices on fish fatty acid profiles. According to Turchini *et al*. (2009), the lipid composition of aquaculture feed significantly enhances the omega-3 fatty acid content of farmed fish. This aligns with the higher PUFA levels observed in cage-cultured *C. gariepinus*.

The predominance of DHA and EPA in cage-cultured samples underscores their potential as functional foods. As highlighted by Shahidi and Ambigaipalan (2015), DHA is critical for neural development, while EPA plays a key role in reducing inflammation and supporting cardiovascular health. In contrast, the higher MUFA levels in wild fish reflect their natural diet, which typically includes algae and plant matter rich in monounsaturated fats (Sargent *et al*., 2002). However, the absence of EPA and DHA in wild fish raises concerns about their comparability with cultured fish for therapeutic purposes. These results also align with Golden *et al*. (2016), who emphasized the bioavailability of micronutrients in farmed fish, highlighting their role in combating malnutrition and non-communicable diseases. The cage-cultured *C. gariepinus* offers a consistent and enhanced source of omega-3 PUFAs, making it a valuable candidate for functional food development.

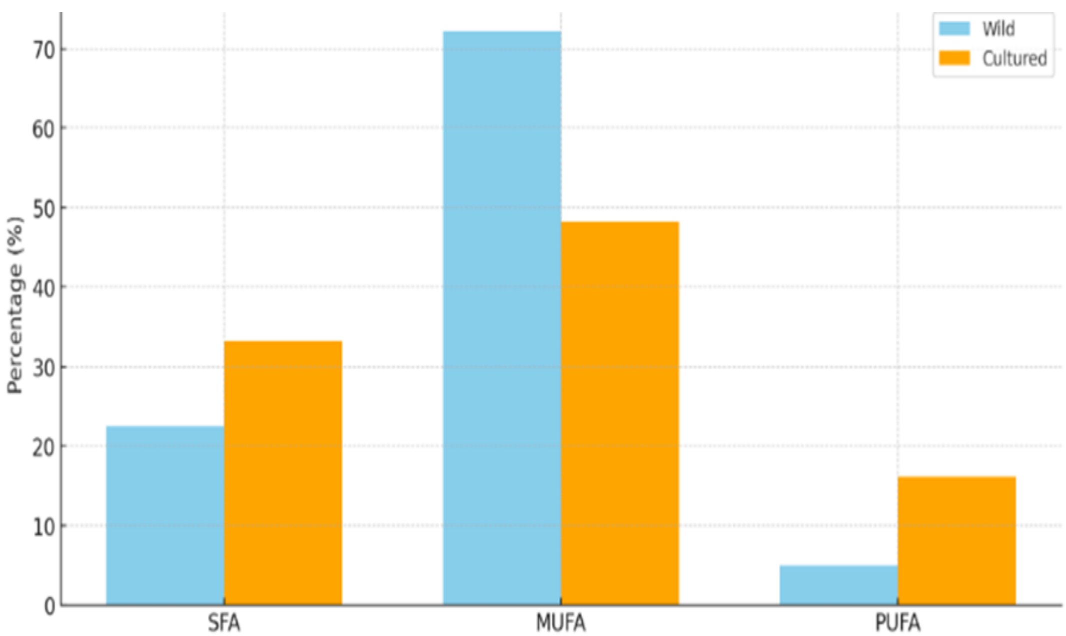

Figure 1: Grouped fatty acid categories of African Catfish

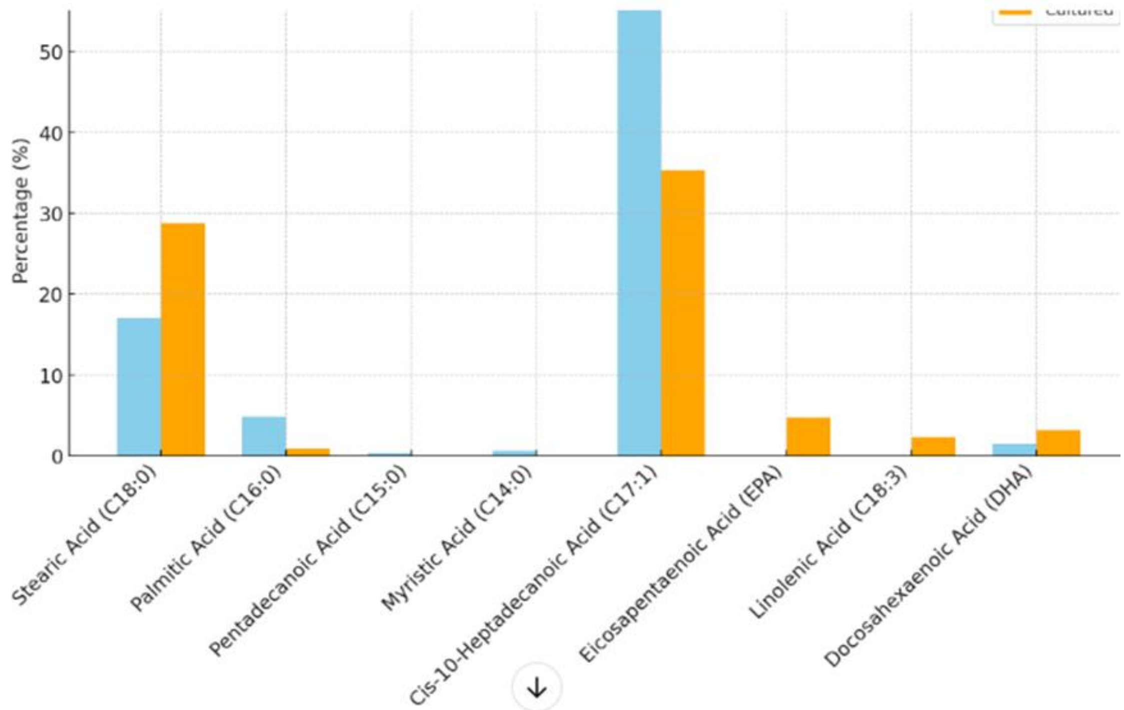

Figure 2: Fatty acid composition of African Catfish (Wild and Cultured)

Conclusion

The study underscores the superior nutritional value of cage-cultured ***C. gariepinus***, particularly in terms of PUFAs like DHA and EPA. This analysis reaffirms ***C. gariepinus*** as a valuable functional food. Its fatty acid profile (particularly in cage-cultured fish), highlights its role in delivering essential nutrients that support human health, offering a promising avenue for nutritional interventions in both developed and developing regions.

These findings also align with global research on the impact of aquaculture practices and environmental variables on fatty acid composition, emphasizing the potential of farmed fish as functional foods and nutraceutical. Future research could further explore sustainable feed innovations to enhance omega-3 levels while reducing reliance on fish oil.

The empirical findings, supported by systematic literature review, demonstrate the superiority of cage-cultured *C. gariepinus* in delivering higher levels of omega-3 PUFAs and essential nutrients. These findings reinforce the role of aquaculture in improving the nutritional value of fish, providing a strong basis for promoting farmed catfish as a functional food and nutraceutical source.

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