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RESEARCH PAPER

Nutritional Profile of Economically Valuable Fish Species in the Lake Victoria Basin: Implications for Food and Nutrition Security Among Local Communities

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Abstract

Fish can help address human nutrient deficiencies but is often overlooked in nutrition policies due to insufficient evidence. This study evaluates the nutritional profiles of five economically significant fish species in the Lake Victoria Basin: Nile tilapia (*Oreochromis niloticus*), Nile perch (*Lates niloticus*), Silver cyprinid (*Rastrineobola argentea*), African catfish (*Clarias gariepinus*), and lungfish (*Protopterus aethiopicus*). A comprehensive literature search was conducted across Google Scholar, PubMed, Web of Science, and Scopus. Studies were screened based on their relevance, methodological rigor, and focus on moisture, ash, lipid, protein content, and fatty acid composition, resulting in the selection of 46 peer-reviewed studies published within the last 20 years. Nile tilapia contains 69.36%–80.03% moisture, 16.40%–23.47% protein, 0.08%–3.77% lipid, and significant omega-3 polyunsaturated fatty acids (PUFAs) (18.9%–33.0%). Nile perch exhibits similar moisture (67.30%–79.6%) and protein (15.93%–22.51%) levels, with lipid content of 0.59%–4.16% and omega-3 PUFAs (12.47%–33.0%). Silver cyprinid shows high variability in protein (15.44%–79.44%) and lipid (0.09%–22.38%) content, with PUFAs comprising 21.68%–35.78%. African catfish has 69.16%–73.54% moisture, 19.93%–23.06% protein, and omega-3 PUFAs ranging from 27.9%–36.9%. Lungfish stands out for its fatty acid diversity, including 35.2%–49.2% PUFAs (13.0%–27.9% omega-3, 11.7%–30.0% omega-6). Although nutritional profiles vary due to environmental and biological factors, all species are nutrient-dense. Thus, promoting the sustainable harvesting and consumption of these fish can contribute substantially to improving dietary quality and nutrition security in communities reliant on Lake Victoria's fisheries.

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Introduction

Lake Victoria, the largest freshwater lake in Africa, is a vital socio-economic linchpin for the East African region, underpinning the livelihoods, food security, and well-being of millions of people (Gesimba, 2020). With an estimated annual production exceeding 500,000 tonnes of fish (Outa et al., 2020), this vast water body not only generates substantial employment but also contributes significantly to both local and regional markets. While the lake supports a diverse array of fish species, only a handful—particularly silver cyprinid (*Rastrineobola argentea*, locally "omena"), Nile perch (*Lates niloticus*), and Nile tilapia (*Oreochromis niloticus*)—have emerged as commercially dominant (SDBF, 2023). Nile perch primarily caters to lucrative regional and international markets, while "omena" and Nile tilapia sustain more localized trade networks. Although indigenous species such as lungfish (*Protopterus aethiopicus*) and catfish (*Clarias gariepinus*) receive less attention in formal catch statistics, they remain culturally and nutritionally important to riparian communities (Okechi, 2022). Over generations, these fisheries have shaped dietary habits, economic structures, and culinary traditions, ensuring steady access to nutrient-rich fish for households around the lake (Aura et al., 2022). The reliance on these fisheries is not merely an economic convenience but a nutritional necessity, as fish consumption in this region represents a crucial strategy for mitigating protein deficiencies and supporting balanced diets.

In recent decades, global fish consumption has surged, reflecting a growing appreciation of fish as a source of high-quality protein and health-promoting nutrients (Bakhsh et al., 2024). This trend is mirrored in the Lake Victoria Basin, where escalating demand for fish aligns with broader nutritional imperatives and health objectives. Central to fish's appeal are their n-3 long-chain polyunsaturated fatty acids (LC-PUFAs)—notably eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)—which have been associated with cardiovascular benefits, optimal neurodevelopment, and reduced risk of metabolic disorders (Martínez-Martínez et al., 2020; Mesa et al., 2021). Beyond lipids, fish also offer a dense matrix of essential nutrients, including high-quality proteins, peptides, and amino acids like methionine, lysine, and taurine, which are often limited in terrestrial meats (Khalili Tilami & Sampels, 2018; Erbay & Yesilsu, 2021). These amino acids and bioactive peptides have drawn scientific interest due to their potential in supporting muscle growth, immune functions, and overall health, making fish a critical ingredient in strategies aimed at alleviating malnutrition and micronutrient deficiencies in vulnerable populations.

However, the nutritional profile of any given fish species is not fixed; it can vary markedly due to multiple ecological and physiological factors. Diet composition, trophic level, and the underlying productivity of the aquatic ecosystem all shape the nutrient content of fish tissues (da Silveira et al., 2020). In Lake Victoria, this variability is particularly salient, given ongoing ecological changes, fluctuating water quality, and shifts in species composition. Additionally, differences in feeding habits—whether planktivorous, benthivorous, or piscivorous—can influence fatty acid profiles and protein content. Environmental conditions such as temperature, dissolved oxygen, and nutrient availability may also affect fish metabolism and nutrient accumulation, adding another layer of complexity to understanding fish-based nutrition within the region (da Silveira et al., 2020). Further, wild fish in Lake Victoria consume natural diets consisting of plankton and benthos, thereby acquiring LC-PUFAs directly from algae—the foundational producers of these beneficial fatty acids (Tilami et al., 2018; Hundal et al., 2021). Freshwater, non-carnivorous species are particularly adept at converting α-linolenic acid (ALA) into more physiologically relevant LC-PUFAs, a trait that not only elevates their nutritional value but also aligns with calls for sustainable, ecosystem-based fisheries management (Tilami et al., 2018).

Despite the crucial role of fisheries in supporting local diets and the evident nutritional value of fish, their contributions often remain underrepresented in policies and dietary guidelines. Decision-makers require detailed, species-specific nutritional data to develop interventions that leverage fish for public health improvements, address micronutrient deficiencies, and promote food system resilience. Yet, the current literature on the nutrient composition of Lake Victoria's most economically significant species is fragmented, with limited quantitative data on their proximate composition, fatty acid profiles, mineral and vitamin content. This paucity of standardized, reliable nutritional information hampers the ability of health practitioners, nutritionists, and community leaders to design evidence-based nutrition programs (Koehn et al., 2022). It also constrains efforts to align fisheries production with evolving dietary recommendations and sustainability goals—objectives that are gaining urgency as governments and international agencies emphasize nutritious, low-impact food sources to achieve sustainable development targets.

As global emphasis intensifies on biodiversity conservation, climate-smart food systems, and nutrition-sensitive policies, a comprehensive understanding of the nutrient profiles of key fish species from Lake Victoria could inform more nuanced approaches to fisheries governance and food security strategies. Detailed insights into the protein, lipid, and micronutrient composition of these fish can help pinpoint their contributions to human health, guiding interventions that bolster dietary diversity and long-term well-being. Such knowledge is particularly relevant for Kenya and other East African nations striving to enhance their nutrition policies, support small-scale fisheries, and respond proactively to environmental changes threatening freshwater ecosystems.

This study aims to address these knowledge gaps by synthesizing the available literature on the nutritional composition of five economically important fish species from the Lake Victoria Basin: Nile tilapia (*O. niloticus*), Nile perch (*L. niloticus*), African catfish (*C. gariepinus*), silver cyprinid (*R. argentea*), and Marbled lungfish (*P. aethiopicus*). Specifically, it compiles data on proximate composition—moisture, ash, lipid, protein content—and fatty acid profiles, as well as minerals and other essential nutrients. In doing so, it provides a baseline for policymakers, nutrition experts, and fisheries managers to harness the full potential of these species, improving nutrition security, guiding sustainable resource management, and contributing to socio-economic development in the Lake Victoria region. This study sets the stage for more targeted interventions, informed dietary recommendations, and strategic frameworks that maximize the health benefits and sustainability of freshwater fisheries.

Materials and methods

The selection of fish species for this study was guided by their economic significance within the Lake Victoria Basin. Species chosen for the review were based on their prominence in local fisheries, market demand, and contribution to the socio-economic well-being of communities around the lake (SDBF, 2023). The species included in this study are Nile tilapia, Nile perch, silver cyprinid, African catfish, and lungfish. A comprehensive literature search was conducted to identify relevant studies on the nutritional composition of the selected fish species. For the literature search, we used multiple electronic databases, including Google Scholar, PubMed, Web of Science, and Scopus. Keywords used in the search included:

- "Nutritive value" AND ("Lake Victoria Basin" OR "East Africa")
- "Nile tilapia," "Nile perch," "Silver cyprinid," "African catfish," "lungfish" AND ("fatty acid composition" OR "protein content" OR "lipid content" OR "mineral content")
- "Influence of temperature on fish nutrition" OR "seasonal variations in fish nutrient composition"
- "Effect of processing methods (smoking, drying, salting, freezing) on fish nutrition"
- "Age and size considerations in fish proximate composition"
- "Sex-based differences in fish nutrient profiles"
- "Sampling and analytical techniques for fish nutrient profiling"

The initial pool of articles was screened in two steps: first, by reviewing titles and abstract to eliminate irrelevant studies, and second, by examining full-texts to ensure they met all inclusion criteria. To be included, studies were preferably peer-reviewed articles, theses, or reports published in English; specifically analysing the nutritional composition (moisture, ash, lipid, protein content, and fatty acid profiles) of selected fish species from the Lake Victoria

Basin. Additionally, the research needed to be conducted within the past 20 years to ensure relevance and up-to-date information. Studies were excluded if they focused on fish species outside the Lake Victoria Basin, did not provide specific quantitative data on nutritional composition, or were published in languages other than English. Following this rigorous selection process, 46 papers were identified as suitable for the review, offering comprehensive and relevant data on the nutritional composition of the fish species in the Lake Victoria Basin.

Data extraction involved collecting quantitative data on the nutritional parameters of interest: moisture, ash, lipid, protein content, and fatty acid profiles, including the proportions of saturated, monounsaturated, and polyunsaturated fatty acids, and n-3 and n-6 fatty acids. Information on mineral content i.e., calcium, iron, magnesium, phosphorus, zinc, and copper was also extracted. The data from each study were tabulated, and the ranges of each nutritional component were calculated. This information was synthesized to provide a comprehensive overview of the nutritional composition of each fish species. The synthesis also involved identifying common trends and variations across studies to understand the influence of environmental, biological, and methodological factors.

Results and Discussion

Nutritional and mineral composition of selected fish species

Nile tilapia (Oreochromis niloticus)

Moisture content is a critical factor influencing the overall quality and shelf life of fish. Raymond et al. (2021) reported a moisture content range of 70.14% to 73.48%, while Muchiri et al. (2015) documented a higher range of 77.93% to 80.03% for tilapia caught from Lake Victoria. Abdulkarim et al. (2016) found moisture content ranging from 69.36% to 74.57% in tilapia collected during different seasons from Mwanza, Magu, and Sengerema on the Tanzanian portion of Lake Victoria. Therefore, the moisture content of Nile tilapia from Lake Victoria ranges from 69.36% to 80.03%, indicating the influence of environmental conditions and seasonal changes on the water content of Nile tilapia.

Ash content, indicative of the mineral composition of fish, varies across different studies. Raymond et al. (2021) reported an ash content of 1.59% to 2.07%, while Muchiri et al. (2015) found a lower range of 0.82% to 1.46%. Abdulkarim et al. (2016) observed a higher ash content ranging from 3.22% to 5.12%. These differences can be attributed to mineral availability in different habitats and seasons. Thus, the ash content of Nile tilapia from Lake Victoria ranges from 0.82% to 5.12%. Lipid content in Nile tilapia is an essential component that impacts the fish's flavor and energy value. Raymond et al. (2021) reported lipid content between 2.85% and 3.77%, while Muchiri et al. (2015) documented a slightly lower range of 1.67% to 3.35%. Abdulkarim et al. (2016) observed a broader range of 0.08% to 3.66%, reflecting the influence of dietary intake and environmental factors on fat accumulation in fish. This relatively low-fat content classifies Nile tilapia as a lean fish, making it a healthy option for consumers looking to reduce their fat intake. Therefore, the lipid content of Nile tilapia from Lake Victoria ranges from 0.08% to 3.77%.

Protein content is a crucial nutritional parameter, especially in regions where fish is a primary protein source. Raymond et al. (2021) reported protein content ranging from 18.72% to 23.47% in Nile tilapia, indicating its high protein value. Muchiri et al. (2015) found protein levels between 16.69% and 18.73%, while Abdulkarim et al. (2016) documented a range of 16.40% to 23.02%. Thus, the protein content of Nile tilapia from Lake Victoria ranges from 16.40% to 23.47%.

The fatty acid composition of Nile tilapia includes both saturated and unsaturated fatty acids, contributing to its nutritional and health benefits. The primary saturated fatty acids reported by Raymond et al. (2021) include caprylic acid (0.77%-1.03%), capric acid (0.05%-0.39%), lauric acid (1.10%-1.50%), myristic acid (2.77%-3.10%), palmitic acid (32.33%-37.30%), stearic acid (12.13%-14.37%), and arachidic acid (0.33%-0.70%). Kwetegyeka et al. (2006) reported myristic ranging 1.3% to 2.3%, pentadecanoic ranging 0.32% to 0.8%, palmitic acid ranging from 19.0% to 30.0% and stearic acid from 9.0% to 13.0% and Arachidic (2%-0.42%). Masa et al. (2011) found myristic acid (0.4%-

1.2%), pentadecanoic (1.1%-1.3%, palmitic acid (23.3%-27.9%), and stearic acid (10.6%-11.6%). Kwetegyeka et al. (2008) documented myristic acid (1.5%-2.3%), pentadecanoic (0.33%-0.41%), palmitic acid (21%-23%), and stearic acid (8.4%-10.4%) and Arachidic 0.21%-0.29%. The presence of these saturated fatty acids is essential for maintaining cellular integrity and metabolic functions. Based on the studies, the ranges for these saturated fatty acids in Nile tilapia from Lake Victoria are as follows: caprylic acid (0.77%-1.03%), capric acid (0.05%-0.39%), lauric acid (1.10%-1.50%), myristic acid (0.4%-3.10%), pentadecanoic (0.32%-1.3%), palmitic acid (19.0%-37.30%), stearic acid (8.4%-14.37%), and arachidic acid (0.2%-0.70%).

Unsaturated fatty acids, known for their health benefits, are also present in Nile tilapia. Raymond et al. (2021) reported palmitoleic acid (5.00%-6.70%), oleic acid (20.70%-21.00%), linoleic acid (6.90%-9.60%), alpha-linolenic acid (0.53%-0.80%), gamma-linolenic acid (0.40%-0.90%), eicosapentaenoic acid (2.17%-2.41%), and docosahexaenoic acid (3.03%-3.70%). Kwetegyeka et al. (2006) reported palmitoleic acid (2-4.5%), oleic acid (4.5%-6.1%), linoleic acid (1.90%-3.40%), alpha-linolenic acid (1.30%-2.50%), gamma-linolenic acid (0.32%-0.58%), eicosapentaenoic acid (2.8%-5.3%), and docosahexaenoic acid (10.0%-16.0%). Masa et al. (2011) found palmitoleic acid (1.70-2.50%), oleic acid (3.6%-4.2%), docosapentaenoic acid (10.0%-16.0%), alpha-linolenic acid (2.0%-2.6%), gamma-linolenic acid (0.5%-2.1%), eicosapentaenoic acid (3.1%-4.3%), and docosahexaenoic acid (12.9%-14.5%). Kwetegyeka et al. (2008) documented palmitoleic acid (3.5%-3.7%), oleic acid (4.2%-6.2%), linoleic acid (1.5%-2.5%), alpha-linolenic acid (2.0%-2.2%), gamma-linolenic acid (0.1-0.3), eicosapentaenoic acid (4.2%-5.0%), and docosahexaenoic acid (18.2%-22.6%). These unsaturated fatty acids, particularly omega-3 and omega-6 fatty acids, are known for their beneficial effects on cardiovascular health, anti-inflammatory properties, and essential roles in brain function. Therefore, the ranges for these unsaturated fatty acids in Nile tilapia from Lake Victoria are as follows: palmitoleic acid (3.5%-6.70%), oleic acid (4.2%-21.00%), linoleic acid (1.5%-9.60%), alpha-linolenic acid (0.53%-2.6%), gamma-linolenic acid (0.1%-2.1%), eicosapentaenoic acid (2.17%-5.3%), and docosahexaenoic acid (3.03%-22.6%) and docosapentaenoic acid (0.9%-6.2%).

The total fatty acid composition of Nile tilapia includes saturated fatty acids ranging from 32% to 50.14%, monounsaturated fatty acids from 11.0% to 21.83%, and polyunsaturated fatty acids from 27.98% to 48.4%. The polyunsaturated fatty acids include omega-3 fatty acids ranging from 18.9% to 33.0% and omega-6 fatty acids from 8.18% to 17% as reported by Kwetegyeka et al. (2006), Masa et al. (2011), and Kwetegyeka et al. (2008). These ranges indicate the diversity of fatty acid profiles in Nile tilapia from different studies.

The mineral composition of Nile tilapia includes calcium, iron, magnesium, phosphorus, and zinc. Raymond et al. (2021) reported calcium levels ranging from 0.377 mg/g to 0.487 mg/g, iron from 0.026 mg/g to 0.031 mg/g, magnesium from 1.221 mg/g to 1.423 mg/g, phosphorus from 0.272 mg/g to 0.328 mg/g, and zinc from 0.046 mg/g to 0.062 mg/g. These minerals are essential for various bodily functions, including bone health, oxygen transport, enzyme function, and cellular metabolism. The mineral content ranges for Nile tilapia from Lake Victoria are as follows: calcium (0.377-0.487 mg/g), iron (0.026-0.031 mg/g), magnesium (1.221-1.423 mg/g), phosphorus (0.272-0.328 mg/g), and zinc (0.046-0.062 mg/g). The ranges for various nutrients and mineral composition of Nile tilapia are summarized in Table 1.

Nile perch (Lates niloticus)

Moisture content is a critical attribute of Nile perch, influencing its texture, taste, and shelf life. Abdulkarim et al. (2016) reported a moisture content range of 67.30% to 75.04%, whereas Okeyo et al. (2009) observed a slightly higher range between 78.5% and 79.6%. High moisture content is typical of freshwater fish and contributes to their desirable tenderness and juiciness, essential for consumer preference.

Ash content, representing the total mineral content, varies significantly across different studies. Abdulkarim et al. (2016) reported ash content ranging from 2.97% to 5.98%, while Okeyo et al. (2009) found much lower values between 0.55% and 0.63%. Higher ash content indicates a rich presence of essential minerals such as calcium, iron, and phosphorus. The lipid content in Nile perch is relatively low, which is advantageous for health-conscious consumers. Abdulkarim et al. (2016) documented lipid levels ranging from 1.48% to 4.16%, and Okeyo et al. (2009) reported even lower lipid content, from 0.59% to 0.63%. Despite its low overall fat content, Nile perch contains a beneficial profile of fatty acids essential for maintaining good health. The low lipid content, coupled with high-quality fats, makes Nile perch an excellent dietary choice for reducing the risk of cardiovascular diseases.

Protein content is a significant attribute of Nile perch, making it a valuable source of high-quality protein for the local population. Abdulkarim et al. (2016) reported protein levels between 15.93% and 22.51%, while Okeyo et al. (2009) found slightly lower values, ranging from 17.7% to 19.8% (Table 2).

Table 1. Nutrient and mineral content ranges for wild Nile tilapia from Lake Victoria

Nutrients	Ranges	Reference
Moisture (%)	69.36-80.03	Raymond et al. (2021); Muchiri et al. (2015); Abdulkarim et al. (2016)
Ash (%)	0.82-5.12	
Lipid (%)	0.08-3.77	
Protein (%)	16.4-23.47	
Saturated fatty acids		
Caprylic Acid (C8:0)	0.77-1.03	Raymond et al. (2021); Kwetegyeka et al. (2006); Masa et al. (2011); Kwetegyeka et al. (2008)
Capric Acid (C10:0)	0.05-0.39	
Lauric Acid (C12:0)	1.1-1.5	
Myristic Acid (C14:0)	0.4-3.1	
Pentadecanoic (C15:0)	0.32-1.3	
Palmitic Acid (C16:0)	19.0-37.3	
Stearic Acid (C18:0)	8.4-14.37	
Arachidic Acid (C20:0)	0.2-0.7	
Unsaturated Fatty Acid		
Palmitoleic Acid (C16:1n-7)	3.5-6.7	Raymond et al. (2021); Kwetegyeka et al. (2006); Masa et al. (2011); Kwetegyeka et al. (2008)
Oleic Acid (C18:1n-9)	4.2-21.0	
Linoleic Acid (C18:2n-6)	1.5-9.6	
Alpha-Linolenic Acid (C18:3n-3)	0.53-2.6	
Gamma-Linolenic Acid (C18:3)	0.1-2.1	
Eicosapentaenoic Acid (C20:5)	2.17-5.3	
Docosahexaenoic Acid (C22:6)	3.03-22.06	
Docosapentaenoic acid (DHA;C22:5n-3)	0.9-6.2	
Total Fatty acids		
Saturated fatty acids (%)	32.0-50.14	Kwetegyeka et al. (2006); Masa et al. (2011); Kwetegyeka et al. (2008)
Monounsaturated fatty acids (MUFA) (%)	11.0-21.83	
Polyunsaturated fatty acids (PUFA) (%)	27.98-48.4	
PUFA N-3 (%)	18.9-33.0	
PUFA N-6 (%)	8.18-17.0	
Mineral Composition (mg/g)		
Calcium	0.377-0.487	Raymond et al. (2021)
Iron	0.026-0.031	
Magnesium	1.221-1.423	
Phosphorus	0.272-0.328	
Zinc	0.046-0.062	
Copper	0.0046-0.0073	

The fatty acid composition of Nile perch includes both saturated and unsaturated fatty acids, which are essential for various metabolic functions and overall health. Saturated fatty acids reported by Ogwok et al. (2009) include myristic acid (0.5%-1.08%), palmitic acid (22.45%-27.84%), and stearic acid (5.93%-7.74%). Namulawa et al. (2011) noted lauric (0.11%-0.25%), myristic acid (0.89%-4.1%), pentadecanoic (0.32%-1.34%), palmitic acid (20.3%-24.54%), and stearic acid

(8.33%-14.04%). Kwetegyeka et al. (2006) recorded myristic acid (0.71%-2.2%), pentadecanoic (0.3%-0.51%), palmitic acid (18.0%-24.0%), stearic acid (18.0%-12.0%), and arachidic (0.25%-0.39%). Masa et al. (2011) noted myristic acid (1.1%-1.7%), pentadecanoic (0.6%-1.0%), palmitic acid (19.0%-21.8%), and stearic acid (9.3%-10.5%). Kyategyeka et al. (2008) noted myristic acid (1.2%-1.4%), pentadecanoic (0.3%-0.5%), palmitic acid (17.6%-21.0%), stearic acid (9.8%-10.8%) and achidic (0.2%-0.4%).

Unsaturated fatty acids, which are beneficial for cardiovascular health, are well represented in Nile perch. Ogwok et al. (2009) reported ranges for palmitoleic acid (11.82%-17.35%), oleic acid (16.47%-23.47%), linoleic acid (1.32%-2.1%), alpha-linolenic acid (1.61%-2.0%), eicosapentaenoic acid (1.94%-3.96%), docosahexaenoic acid (5.06%-10.02%) and docosapentaenoic (3.32%-5.76%). Namulawa et al. (2011) found palmitoleic acid (2.89%-7.79%), oleic acid (8.54%-16.94%), linoleic acid (0.73%-4.03%), alpha-linolenic acid (0.29%-4.88%), gamma-linolenic acid (0%-12.98%), eicosapentaenoic acid (0.74%-6.0%), docosahexaenoic acid (4.89%-13.72%), and docosapentaenoic acid (3.08%-4.34%). Okoth et al. (2015) documented eicosapentaenoic acid (2.45%-3.07%) and docosahexaenoic acid (7.34%-7.66%). Kwetegyeka et al. (2006) reported palmitoleic acid (1.2%-6.0%), oleic acid (5.7%-8.0%), linoleic acid (1.0%-3.2%), alpha-linolenic acid (0.6%-2.5%), gamma-linolenic acid (0.3%-0.7%), eicosapentaenoic acid (4.4%-7.0%), docosahexaenoic acid (8.0%-17.0%), and docosapentaenoic acid (4.7%-7.0%). Masa et al. (2011) observed palmitoleic acid (4.9%-6.3%), oleic acid (3.2%-4.0%), alpha-linolenic acid (1.5%-2.3%), gamma-linolenic acid (0.5%-1.9%), eicosapentaenoic acid (3.8%-5.2%), docosahexaenoic acid (15.0%-16.8%), and docosapentaenoic acid (1.5%-2.5%). Lastly, Kwetegyeka et al. (2008) found palmitoleic acid (1.8%-3.0%), oleic acid (7.8%-9.6%), linoleic acid (1.6%-2.6%), alpha-linolenic acid (1.4%-1.8%), gamma-linolenic acid (0.1%-0.3%), eicosapentaenoic acid (3.2%-3.6%), docosahexaenoic acid (17.1%-19.1%), and docosapentaenoic acid (4.6%-6.2%).

The total fatty acid composition in Nile perch includes a balance of saturated, monounsaturated, and polyunsaturated fatty acids. Ogwok et al. (2009) reported saturated fatty acids ranging from 32.66% to 42.95%, monounsaturated fatty acids (MUFA) from 32.55% to 41.0%, polyunsaturated fatty acids (PUFA) from 15.67% to 23.52%, PUFA N-3 from 12.47% to 21.45%, and PUFA N-6 from 1.9% to 3.86%. Namulawa et al. (2011) documented saturated fatty acids from 34.44% to 42.68%, MUFA from 20.92% to 33.92%, PUFA from 23.77% to 35.19%, PUFA N-3 from 15.36% to 20.02%, and PUFA N-6 from 11.12% to 13.94%. Kwetegyeka et al. (2006) found saturated fatty acids ranging from 31.0% to 43.0%, MUFA from 14.0% to 27.0%, PUFA from 30.0% to 47.0%, PUFA N-3 from 20.0% to 33.0%, and PUFA N-6 from 10.0% to 18.0%. Masa et al. (2011) reported saturated fatty acids from 30.3% to 35.9%, MUFA from 24.3% to 28.7%, PUFA from 31.9% to 39.9%, PUFA N-3 from 21.8% to 26.8%, and PUFA N-6 from 10.1% to 13.1%. Kwetegyeka et al. (2008) documented saturated fatty acids from 33.6% to 34.6%, MUFA from 18.9% to 19.5%, PUFA from 46.4% to 47.0%, PUFA N-3 from 27.0% to 27.8%, and PUFA N-6 from 14.9% to 15.5%. These ranges highlight the nutritional diversity of Nile perch and its potential health benefits.

Silver cyprinid (Rastrineobola argentea)

The nutritional profile of *R. argentea* is highlighted by various proximate composition analyses, underscoring its importance as a dietary component for local communities. Moisture content in this fish shows considerable variation across different studies. Ogonda et al. (2014) reported moisture content ranging from 72.83% to 76.90% on a wet-weight basis, reflecting the high-water content typical of freshwater fish and contributing to its juiciness and tenderness. In contrast, Abdulkarim et al. (2016) found a slightly broader range from 70.26% to 77.40%. Notably, Chaula et al. (2019) observed a lower moisture content range of 7.85% to 17.84%, likely due to the drying process commonly applied to Dagaa. Kubiriza et al. (2021) reported an even wider range from 5.81% to 20.26%, while Omagor et al. (2020) found moisture content between 16.5% and 27.2%. Overall, the moisture content for *R. argentea* from Lake Victoria ranges from 5.81%

to 77.40%, demonstrating significant variation due to different processing methods and environmental factors.

Ash content, indicative of the total mineral content, also shows considerable variation among studies. Ogonda et al. (2014) reported ash content ranging from 1.88% to 4.38%, while Abdulkarim et al. (2016) found higher values between 3.87% and 7.66%. Kubiriza et al. (2021) observed a wide range from 7.57% to 25.36%, reflecting the significant mineral presence in *R. argentea*. These variations highlight the importance of Omena as a source of essential minerals such as calcium, phosphorus, and iron, which are crucial for bone health, oxygen transport, and metabolic processes. The ash content for *R. argentea* from Lake Victoria ranges from 1.88% to 25.36%.

Lipid content in *R. argentea* is essential for its energy value and flavor. Ogonda et al. (2014) reported lipid content ranging from 1.77% to 7.78%, indicating moderate fat levels that contribute to the fish's taste and caloric value. Abdulkarim et al. (2016) found a lower lipid range from 0.09% to 1.63%, whereas Chaula et al. (2019) documented a broader range from 10.19% to 22.38%, likely due to variations in the fish's diet and environmental conditions. Kubiriza et al. (2021) reported lipid content between 12.09% and 17.11%, and Omagor et al. (2020) found lipid levels ranging from 10.3% to 15.0%. Overall, the lipid content for *R. argentea* from Lake Victoria ranges from 0.09% to 22.38%.

Table 2. Nutrient and mineral content ranges for Nile perch from Lake Victoria

Nutrients	Ranges	Reference
Moisture (%)	67.30-79.6	Abdulkarim et al. (2016); Okeyo et al. (2009)
Ash (%)	0.55-5.98	
Lipid (%)	0.59-4.16	
Protein (%)	15.93-22.51	
Saturated fatty acids		
Lauric Acid (C12:0)	0.11-0.25	
Myristic Acid (C14:0)	0.5-4.1	Namulawa et al. (2011); Ogwok et al. (2009); Kwetegyeka et al. (2006); Masa et al. (2011); Kwetegyeka et al. (2008)
Pentadecanoic (C15:0)	0.3-1.34	
Palmitic Acid (C16:0)	17.6-27.84	
Stearic Acid (C18:0)	5.93-14.04	
Arachidic Acid (C20:0)	0.2-0.4	
Unsaturated Fatty Acid		
Palmitoleic Acid (C16:1n-7)	1.8-17.35	Ogwok et al. (2009); Namulawa et al. (2011); Kwetegyeka et al. (2006); Masa et al. (2011); Kwetegyeka et al. (2008); Okoth et al. (2015)
Oleic Acid (C18:1n-9)	3.2-23.47	
Linoleic Acid (C18:2n-6)	0.73-4.03	
Alpha-Linolenic Acid (C18:3n-3)	0.29-4.88	
Gamma-Linolenic Acid (C18:3)	0.0-12.98	
Eicosapentaenoic Acid (C20:5)	0.74-7.0	
Docosahexaenoic Acid (C22:6)	4.89-19.1	
Docosapentaenoic acid (DHA;C22:5n-3)	1.5-7.0	
Total Fatty acids		
Saturated fatty acids (%)	30.3-43.0	Ogwok et al. (2009); Namulawa et al. (2011); Kwetegyeka et al. (2006); Masa et al. (2011); Kwetegyeka et al. (2008)
Monounsaturated fatty acids (MUFA) (%)	14.0-41.0	
Polyunsaturated fatty acids (PUFA) (%)	15.67-47.0	
PUFA N-3 (%)	12.47-33.0	
PUFA N-6 (%)	1.9-18.0	

Protein content in *R. argentea* is one of its most valuable nutritional attributes, especially in regions where alternative protein sources are limited. Ogonda et al. (2014) reported protein levels ranging from 19.11% to 21.78%, which is relatively high for fish. Abdulkarim et al. (2016)

found a protein range from 15.44% to 21.20%. Chaula et al. (2019) did not provide specific protein values, but Kubiriza et al. (2021) reported exceptionally high protein content ranging from 52.61% to 79.44%, reflecting the fish's importance as a protein source. Omagor et al. (2020) documented protein content from 62.6% to 71.4%.. Therefore, the protein content for *R. argentea* from Lake Victoria ranges from 15.44% to 79.44%.

The fatty acid composition of *R. argentea* includes both saturated and unsaturated fatty acids, which are crucial for various health benefits. Mwanja and Munguti (2010) reported myristic acid (1.24%-2.91%), palmitic acid (22%-37%), stearic acid (12.43%-17.16%), and arachidic acid (0.06%-0.29%). Chaula et al. (2019) documented myristic acid (0.62%-3.63%), pentadecanoic acid (0.55%-0.71%), palmitic acid (12.62%-24.13%), stearic acid (1.77%-7.84%), and arachidic acid (0.22%-0.46%).

Unsaturated fatty acids, known for their cardiovascular benefits, are also well-represented in *R. argentea*. Mwanja and Munguti (2010) reported palmitoleic acid (1.91%-3.79%), oleic acid (7.08%-9.94%), linoleic acid (4.69%-7.77%), alpha-linolenic acid (2.01%-3.83%), eicosapentaenoic acid (1.2%-4.2%), and docosahexaenoic acid (3.2%-8.88%). Chaula et al. (2019) found palmitoleic acid (2.57%-11.92%), oleic acid (2.63%-5.3%), linoleic acid (0.4%-2.78%), alpha-linolenic acid (0.02%-0.47%), gamma-linolenic acid (0.13%-0.31%), eicosapentaenoic acid (1.35%-6.9%), docosahexaenoic acid (6.67%-13.38%), and docosapentaenoic acid (1.58%-2.31%). The presence of these fatty acids in Omena makes it a beneficial dietary component for supporting heart health and cognitive functions.

The total fatty acid composition in *R. argentea*, as reported by Mwanja and Munguti (2010), included 47.57% saturated fatty acids, 16.67% monounsaturated fatty acids (MUFA), and 35.78% polyunsaturated fatty acids (PUFA), with PUFA N-3 and PUFA N-6 accounting for 13.54% and 22.24%, respectively. Chaula et al. (2019) found saturated fatty acids ranging from 14.75% to 42.24%, MUFA from 5.93% to 24.41%, PUFA from 21.68% to 31.68%, PUFA N-3 from 15.13% to 24.59%, and PUFA N-6 from 1.64% to 6.5%. Based on the various studies, the nutrient and mineral content ranges for Silver cyprinid from Lake Victoria have been summarized in Table 3.

African catfish (Clarias gariepinus)

The African catfish (*Clarias gariepinus*) is a prominent fish species in the Lake Victoria Basin, Kenya, valued for both its nutritional content and economic significance. The moisture content in African catfish is notably high (Table 4), a characteristic feature of freshwater fish that contributes to their desirable texture and taste. Raymond et al. (2021) reported moisture levels ranging from 69.16% to 73.54%. Such high moisture content is beneficial as it enhances the fish's tenderness and juiciness, attributes that are particularly appreciated by consumers.

Ash content, which reflects the total mineral content of the fish, varies among studies but consistently shows the presence of significant mineral quantities. Raymond et al. (2021) found ash content ranging from 1.60% to 2.29%. These values indicate a substantial presence of minerals essential for various body functions, including bone formation, enzymatic activities, and overall metabolic processes. The lipid content in African catfish, as reported by Raymond et al. (2021), ranges from 2.84% to 4.13%. Although this places African catfish in a moderate lipid category, the fat content is crucial for energy provision and the absorption of fat-soluble vitamins. Fats also contribute to the fish's flavor profile, making it a vital dietary component. According to Raymond et al. (2021), the protein content of African catfish is notably high, ranging from 19.93% to 23.06%.

The fatty acid composition of African catfish is diverse, including both saturated and unsaturated fatty acids. Saturated fatty acids, as reported by Raymond et al. (2021), include caprylic acid (0.77%-1.03%), capric acid (0.06%-0.09%), lauric acid (1.33%-1.70%), myristic acid (2.90%-3.23%), palmitic acid (33.63%-38.20%), stearic acid (10.80%-12.20%), and arachidic acid (0.40%-0.87%). Masa et al. (2011) documented myristic acid (1.1%-2.5%), palmitic acid (21.7%-24.9%), and stearic acid (11.3%-12.7%).

Unsaturated fatty acids, known for their positive health impacts, are well-represented in African catfish. Raymond et al. (2021) reported palmitoleic acid (4.33%-5.20%), oleic acid (20.50%-22.40%), linoleic acid (6.60%-8.60%), alpha-linolenic acid (0.50%-1.17%), gamma-linolenic acid (0.50%-0.90%), eicosapentaenoic acid (1.57%-2.23%), and docosahexaenoic acid (3.33%-3.77%). Masa et al. (2011) found palmitoleic acid (3.6%-4.8%), oleic acid (4.9%-5.9%), alpha-linolenic acid (2.4%-3.2%), gamma-linolenic acid (0.6%-1.8%), eicosapentaenoic acid (3.5%-4.3%), and docosahexaenoic acid (9.9%-12.1%).

The total fatty acid composition shows a balance between different types of fatty acids. Masa et al. (2011) reported saturated fatty acids ranging from 35.5% to 42.1%, monounsaturated fatty acids from 18.4% to 22.4%, and polyunsaturated fatty acids from 29.7% to 36.9%. Polyunsaturated fatty acids include omega-3 fatty acids, which range from 27.9% to 36.9%, and omega-6 fatty acids, ranging from 12.1% to 14.5%.

Table 3. Nutrient and mineral content ranges for Silver cyprinid from Lake Victoria

Nutrients	Ranges	Reference
Moisture (%)	5.81-77.40	Ogonda et al. (2014); Abdulkarim et al. (2016); Chaula et al. (2019); Kubiriza et al. (2021); Omagor et al. (2020)
Ash (%)	1.88-25.36	
Lipid (%)	0.09-22.38	
Protein (%)	15.44-79.44	
Saturated fatty acids		
Myristic Acid (C14:0)	0.62-3.63	Mwanja & Munguti (2010); Chaula et al. (2019)
Pentadecanoic (C15:0)	0.55-0.71	
Palmitic Acid (C16:0)	12.62-37.0	
Stearic Acid (C18:0)	1.77-17.16	
Arachidic Acid (C20:0)	0.06-0.46	
Unsaturated Fatty Acid		
Palmitoleic Acid (C16:1n-7)	1.91-11.92	Mwanja & Munguti (2010); Chaula et al. (2019)
Oleic Acid (C18:1n-9)	2.63-9.94	
Linoleic Acid (C18:2n-6)	0.4-7.77	
Alpha-Linolenic Acid (C18:3n-3)	0.02-3.83	
Gamma-Linolenic Acid (C18:3)	0.13-0.31	
Eicosapentaenoic Acid (C20:5)	1.2-6.9	
Docosahexaenoic Acid (C22:6)	3.2-13.38	
Docosapentaenoic acid (DHA;C22:5n-3)	1.58-2.31	
Total Fatty acids		
Saturated fatty acids (%)	14.75-47.57	Mwanja & Munguti (2010); Chaula et al. (2019)
Monounsaturated fatty acids (MUFA) (%)	5.93-24.41	
Polyunsaturated fatty acids (PUFA) (%)	21.68-35.78	
PUFA N-3 (%)	13.54-24.59	
PUFA N-6 (%)	1.64-22.24	

The mineral composition of African catfish includes vital elements such as calcium, iron, magnesium, phosphorus, zinc, and copper. Raymond et al. (2021) reported calcium levels ranging from 0.413 mg/g to 0.46 mg/g, which are essential for bone health and muscle function. Iron content ranges from 0.024 mg/g to 0.036 mg/g, playing a crucial role in oxygen transport and preventing anemia, particularly in women and children. Magnesium levels, ranging from 1.274 mg/g to 1.385 mg/g, are important for muscle and nerve function, while phosphorus, at 0.28 mg/g to 0.325 mg/g, is vital for energy metabolism and bone health. Zinc levels between 0.044 mg/g to 0.063 mg/g support immune function and wound healing, and copper, ranging from 0.0054 mg/g to 0.007 mg/g, is involved in cardiovascular health and the formation of red blood cells.

Table 4. Nutrient and mineral content ranges for African catfish from Lake Victoria

Nutrients	Ranges	Reference
Moisture (%)	69.16-73.54	Raymond et al. (2021)
Ash (%)	1.6-2.29	
Lipid (%)	2.84-4.13	
Protein (%)	19.93-23.06	
Saturated fatty acids		
Caprylic Acid (C8:0)	0.77 - 1.03	Raymond et al. (2021); Masa et al. (2011)
Capric Acid (C10:0)	0.06 - 0.09	
Lauric Acid (C12:0)	1.33 - 1.70	
Myristic Acid (C14:0)	1.1-3.23	
Pentadecanoic (C15:0)	0.6-0.8	
Palmitic Acid (C16:0)	21.7-38.20	
Stearic Acid (C18:0)	10.80-12.7	
Arachidic Acid (C20:0)	0.40 - 0.87	
Unsaturated Fatty Acid		
Palmitoleic Acid (C16:1n-7)	3.6-5.2	Raymond et al. (2021); Masa et al. (2011)
Oleic Acid (C18:1n-9)	4.9-22.4	
Linoleic Acid (C18:2n-6)	6.60 - 8.60	
Alpha-Linolenic Acid (C18:3n-3)	0.50-3.2	
Gamma-Linolenic Acid (C18:3)	0.50-1.8	
Eicosapentaenoic Acid (C20:5)	1.57-4.3	
Docosahexaenoic Acid (C22:6)	3.33-12.1	
Docosapentaenoic acid (DHA;C22:5n-3)	1.8-2.8	
Total Fatty acids		
Saturated fatty acids (%)	35.5-42.1	Masa et al. (2011)
Monounsaturated fatty acids (MUFA) (%)	18.4-22.4	
Polyunsaturated fatty acids(PUFA) (%)	29.7-36.9	
PUFA N-3 (%)	27.9-36.9	
PUFA N-6 (%)	12.1-14.5	
Mineral Composition (mg/g)		
Calcium	0.413-0.46	Raymond et al. (2021)
Iron	0.024-0.036	
Magnesium	1.274-1.385	
Phosphorus	0.280-0.325	
Zinc	0.044-0.063	
Copper	0.0054-0.007	

Lungfish (Protopterus aethiopicus)

Lungfish (*Protopterus aethiopicus*) from Lake Victoria is an essential part of the local diet due to its rich nutritional profile, particularly in fatty acids. The saturated fatty acid composition of lungfish reveals significant variation among different studies. Masa et al. (2011) reported myristic acid content ranging from 2.8% to 3.6%, which contributes to the fish's overall fat profile and is important for energy storage and cellular functions. In contrast, Kwetegyeka et al. (2008) found a slightly broader range for myristic acid, between 2.3% and 3.5%. Pentadecanoic acid, a less common saturated fatty acid, was found in substantial amounts by Masa et al. (2011), ranging from 14.7% to 17.1%, while Kwetegyeka et al. (2008) reported much lower values from 0.4% to 0.6%. This significant difference may be due to variations in the fish's diet and habitat conditions. Palmitic acid, a major saturated fatty acid, was found in the range of 8.9% to 9.9% by Masa et al. (2011) and 11.5% to 12.5% by Kwetegyeka et al. (2008). Stearic acid content varied from 0.5% to 0.7% in Masa et al. (2011) and from 9.7% to 11.1% in Kwetegyeka et al. (2008). Arachidic acid was only reported by Kwetegyeka et al. (2008), ranging from 0.2% to 0.4%. Therefore, the ranges for these saturated fatty acids in lungfish from Lake Victoria are: myristic acid (2.3% to 3.6%), pentadecanoic acid (0.4% to 17.1%), palmitic acid (8.9% to 12.5%), stearic acid (0.5% to 11.1%), and arachidic acid (0.2% to 0.4%).

Unsaturated fatty acids are critical for cardiovascular health and cognitive functions, and lungfish from Lake Victoria are rich in these beneficial fats. Masa et al. (2011) reported palmitoleic acid content ranging from 5.1% to 6.7%, which is important for lipid metabolism and cellular signaling. Kwetegyeka et al. (2008) found slightly lower values for palmitoleic acid, ranging from 3.6% to 4.6%. Oleic acid, a monounsaturated fatty acid known for its heart health benefits, ranged from 4.3% to 5.5% in Masa et al. (2011) and from 4.0% to 5.8% in Kwetegyeka et al. (2008). Linoleic acid, an essential omega-6 fatty acid, was reported by Kwetegyeka et al. (2008) to range from 0.9% to 1.1%, although Masa et al. (2011) did not report any values for this fatty acid. Alpha-linolenic acid, an omega-3 fatty acid important for anti-inflammatory processes, ranged from 3.1% to 3.9% in Masa et al. (2011) and from 0.39% to 0.47% in Kwetegyeka et al. (2008). Gamma-linolenic acid, another omega-6 fatty acid, was found to range from 1.8% to 3.0% in Masa et al. (2011) and from 0.05% to 0.11% in Kwetegyeka et al. (2008). Eicosapentaenoic acid (EPA), an important omega-3 fatty acid for heart health, ranged from 5.8% to 6.4% in Masa et al. (2011) and from 2.1% to 2.5% in Kwetegyeka et al. (2008). Docosahexaenoic acid (DHA), another critical omega-3 fatty acid, varied widely, from 11.9% to 14.5% in Masa et al. (2011) to 5.1% to 10.5% in Kwetegyeka et al. (2008). Docosapentaenoic acid (DPA), a lesser-known but important omega-3 fatty acid, ranged from 2.7% to 3.1% in Masa et al. (2011) and from 3.5% to 4.9% in Kwetegyeka et al. (2008). Therefore, the ranges for these unsaturated fatty acids in lungfish from Lake Victoria are: palmitoleic acid (3.6% to 6.7%), oleic acid (4.0% to 5.8%), linoleic acid (0.9% to 1.1%), alpha-linolenic acid (0.39% to 3.9%), gamma-linolenic acid (0.05% to 3.0%), eicosapentaenoic acid (2.1% to 6.4%), docosahexaenoic acid (5.1% to 14.5%), and docosapentaenoic acid (2.7% to 4.9%).

The total fatty acid composition of lungfish highlights its rich and balanced fatty acid profile. Masa et al. (2011) reported that the saturated fatty acids ranged from 27.7% to 32.5%, monounsaturated fatty acids (MUFA) from 21.4% to 26.4%, and polyunsaturated fatty acids (PUFA) from 35.2% to 42.6%. PUFA N-3, essential omega-3 fatty acids, ranged from 23.5% to 27.9%, and PUFA N-6, omega-6 fatty acids, ranged from 11.7% to 14.7%. Kwetegyeka et al. (2008) found saturated fatty acids ranging from 30.3% to 30.7%, MUFA from 20.8% to 21.4%, and PUFA from 47.6% to 49.2%. The PUFA N-3 ranged from 13.0% to 15.0%, and PUFA N-6 from 28.0% to 30.0%. These variations in fatty acid composition underscore the nutritional diversity of lungfish and its potential health benefits. The ranges for total fatty acids in lungfish from Lake Victoria are saturated fatty acids (27.7% to 32.5%), monounsaturated fatty acids (20.8% to 26.4%), polyunsaturated fatty acids (35.2% to 49.2%), PUFA N-3 (13.0% to 27.9%), and PUFA N-6 (11.7% to 30.0%). The nutritional value for lungfish based on the various studies has been summarized in Table 5.

Influence of environmental, dietary, biological, and methodological factors on the nutritive value of fish species in Lake Victoria Basin

Despite the clear nutritional benefits, it is important to acknowledge the limitations and variations in the reported nutrient levels across different studies. Several factors can significantly influence nutrient composition. For instance, environmental conditions play a crucial role in determining the nutritional profile of fish (Zhang et al., 2020). For instance, water temperature directly influences fish metabolic rates, thereby affecting lipids and protein accumulation. In warmer waters, fish tend to have increased metabolic rates, which can lead to higher fat content as they store more energy (Morash et al., 2021).

Table 5: Nutrient content ranges for lungfish from Lake Victoria

Saturated fatty acids	Ranges (%)	Reference
Myristic Acid (C14:0)	2.3-3.6	Masa et al. (2011); Kwetegyeka et al. (2008)
Pentadecanoic (C15:0)	0.4-17.1	
Palmitic Acid (C16:0)	8.9-12.5	
Stearic Acid (C18:0)	0.5-11.1	
Arachidic Acid (C20:0)	0.2-0.4	
Unsaturated fatty acids		
Palmitoleic Acid (C16:1n-7)	3.6-6.7	Masa et al. (2011); Kwetegyeka et al. (2008)
Oleic Acid (C18:1n-9)	4.0-5.8	
Linoleic Acid (C18:2n-6)	0.9-1.1	
Alpha-Linolenic Acid (C18:3n-3)	0.39-3.9	
Gamma-Linolenic Acid (C18:3)	0.05-3.0	
Eicosapentaenoic Acid (C20:5)	2.1-6.4	
Docosahexaenoic Acid (C22:6)	5.1-14.5	
Docosapentaenoic acid (DHA;C22:5n-3)	2.7-4.9	
Total fatty acids		
Saturated fatty acids (%)	27.7-32.5	Masa et al. (2011); Kwetegyeka et al. (2008).
Monounsaturated fatty acids (MUFA) (%)	20.8-26.4	
Polyunsaturated fatty acids (PUFA) (%)	35.2-49.2	
PUFA N-3 (%)	13.0-27.9	
PUFA N-6 (%)	11.7-30.0	

Conversely, the metabolic rate decreases in cooler waters, potentially resulting in lower lipid deposition. For example, Nile tilapia from Lake Victoria shows a lipid content ranging from 0.08% to 3.77% across different studies, indicating the influence of varying environmental conditions (Raymond et al., 2021; Muchiri et al., 2015; Abdulkarim et al., 2016). Water quality, including the presence of pollutants and nutrients, also significantly impacts fish health and nutrient composition. Fish living in cleaner, nutrient-rich waters are generally healthier and exhibit higher protein and mineral content (Thilsted et al., 2016). This can be attributed to better overall growth conditions and less metabolic stress compared to fish from polluted waters, where the presence of contaminants can lead to altered metabolic pathways and nutrient deficiencies.

Seasonal variations can also complicate the nutritional analysis of fish. Seasonal changes, such as temperature fluctuations and variations in food availability, can have profound effects on fish metabolism and nutrient storage (Costalago et al., 2020). During colder months, fish may accumulate more lipids to provide insulation against the cold, resulting in higher fat content (Brodte et al., 2008). For instance, African catfish showed lipid content ranging from 2.84% to 4.13% (Raymond et al., 2021), which might vary with seasonal changes. In contrast, warmer temperatures in other seasons can increase metabolic activity, leading to higher protein and moisture content.

Additionally, the seasonal availability of food sources impacts the diet of fish, subsequently affecting their nutrient composition. During times of food abundance, fish may consume a diet rich in nutrients, resulting in higher protein and fat content (de Souza et al., 2020). Conversely, nutrient content may decrease during lean seasons as fish rely on stored reserves, leading to fluctuations in their nutritional profiles. The reproductive cycle also plays a significant role, with nutrient levels in fish often changing during spawning seasons as nutrients are redirected towards gonad development, reducing their presence in muscle tissues (Singh et al., 2021).

Diet and feeding habits of the various species are also critical factors influencing the nutritional composition of fish (Ahmed et al., 2022). The natural diet of fish in Lake Victoria varies widely, affecting their nutrient profiles. Carnivorous fish typically have higher protein content due to their meat-based diet, while omnivorous species exhibit a more varied nutrient profile that reflects their diverse dietary intake (Jauralde et al., 2021). For example, protein content in Nile tilapia ranges from 16.40% to 23.47% (Raymond et al., 2021; Muchiri et al., 2015; Abdulkarim et al., 2016), highlighting the influence of diet on nutrient levels.

Biological factors, including genetic variation, age, size, and sex, also contribute to differences in nutrient composition among fish species (Ahmed et al., 2022). Genetic differences can lead to variations in metabolic efficiency and nutrient storage mechanisms, resulting in distinct nutrient profiles even within the same species. For instance, genetic variation in Nile tilapia collected in different sampling sites could explain the differences in protein content observed across different studies (Raymond et al., 2021; Muchiri et al., 2015; Abdulkarim et al., 2016). Age and size are important determinants as younger fish often have higher metabolic rates and different nutrient needs compared to older fish. Larger fish may also have more fat reserves, influencing their overall nutrient content. For example, lipid content in African catfish varies from 2.84% to 4.13%, possibly due to differences in age and size of fish sampled from the various studies (Raymond et al., 2021). Additionally, sex-related differences in nutrient composition are particularly evident during reproductive seasons when nutrient allocation varies between males and females, affecting the levels of certain nutrients in their tissues.

Methodological differences in how fish samples are collected, handled, and analyzed can introduce variability in the reported nutrient composition. Sampling methods, such as the time of day and location of fish capture, can significantly affect nutrient measurements. For instance, the study by Raymond et al. (2021) could have reported different moisture and lipid contents compared to Muchiri et al. (2015) and Abdulkarim et al. (2016) due to variations in sampling locations and times. Raymond et al. (2021) collected samples from vendors early in the morning, which may have affected freshness compared to fish captured directly from the wild in other studies.

Moreover, post-harvest handling, processing, and storage methods can lead to metabolic changes that alter nutrient composition (Ojelade et al., 2023). Common preservation techniques, such as drying and smoking, can alter the nutrient profile of fish. Drying, for instance, reduces moisture content and can concentrate other nutrients, while smoking can introduce additional compounds and affect the levels of certain nutrients. For example, the study by Namwanje et al. (2021) reported lower moisture and higher ash contents in dried silver cyprinid compared to fresh samples reported by Ogonda et al. (2014) and Abdulkarim et al. (2016). The conditions under which fish are stored, such as temperature and duration of storage, also influence nutrient stability. Lipids, in particular, are susceptible to oxidation, which can degrade their quality over time. Ogonda et al. (2014) ensured that fish were transported on ice and stored frozen until analysis, which could prevent nutrient degradation, whereas Okeyo et al. (2009) noted the influence of transportation duration and storage temperature on the lipid content of Nile perch, showing significant differences when samples were stored at 0-2°C compared to samples analyzed immediately.

Furthermore, variations in analytical techniques used by different laboratories can lead to discrepancies in reported values. Differences in sample preparation, such as drying and homogenizing, can also introduce variability, as can the specific methods used to measure nutrients, such as proximate analysis, gas chromatography, and spectrophotometry. For example, Namulawa et al. (2011) and Kwetegyeka et al. (2008) used different protocols for esterification and gas chromatography in analyzing fatty acids, leading to potential variations in reported fatty acid profiles. In Namulawa et al. (2011), samples were methanolysed and all fatty acids converted to their methyl esters in the methanolic solution, while Kwetegyeka et al. (2008) included a nitrogen flushing step and used a different gas chromatography setup, which could influence the detection and quantification of fatty acids. These methodological differences highlight the need for standardized procedures to ensure consistency and accuracy in nutritional analysis.

Implications on Community Nutritional Profile

The nutritional profile of economically valuable fish species in the Lake Victoria Basin holds substantial implications for the nutritional security of local communities. Species such as Nile perch and Nile tilapia, are rich sources of essential nutrients including omega-3 fatty acids, proteins, vitamins, and minerals, which are pivotal for brain development, cardiovascular health, and general wellness according to the FAO (2014). Fish is not only a staple in the diets of these communities but also a cornerstone of food security, providing a reliable and high-quality protein source as highlighted in the World Bank's 2016 report.

Economically, fishing is a lifeline for millions around Lake Victoria, with activities related to fishing, such as processing and trading, bolstering community livelihoods, enhancing welfare, and reducing poverty levels (Awange & Awange, 2021). Additionally, the cultural relevance of fish consumption is profound and ingrained in the local diet and practices, thus supporting community cohesion and traditional nutrition practices (Morgan et al., 2017). To fully realize Kenya's potential in aquaculture and enhance the country's food and nutrition status, deliberate efforts must be made to foster an environment that encourages both public and private investment in the industry.

However, these communities also face vulnerabilities due to overfishing and environmental changes that threaten the sustainability of these fish resources (FAO, 2022). The Cochrane et al. (2011) study emphasizes the necessity for sustainable fishing practices to ensure these resources can support future generations. This multifaceted impact underscores the critical role that the nutritional profile of local fish species plays in shaping the economic, cultural, and nutritional dimensions of communities in the Lake Victoria Basin.

Conclusion

The diverse fish species of economic importance in the Lake Victoria Basin, including Nile tilapia, Nile perch, silver cyprinid, African catfish, and lungfish, exhibit significant nutritional value, underscoring their vital role in the dietary needs and economic livelihoods of local communities. These fish provide high-quality protein, essential fatty acids, and key minerals, which contribute to overall health and well-being. The variability in nutrient content observed across different studies highlights the influence of environmental factors, diet, biological and methodological differences, underscoring the need for standardized analytical approaches to ensure accurate nutritional profiling. Given their rich nutritional profiles, promoting the sustainable management and consumption of these fish species can enhance food security, support public health, and drive socio-economic development in the region.

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Ethical approval

The authors declare that this study complies with research and publication ethics.

Informed consent

Not available

Data Availability

Data sharing does not apply to this article as no new data is created or analyzed in this study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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