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Toxic Effects of Raffia Palm (*Raphia hookeri*) Fruit Mesocarp on *Oreochromis niloticus* in Epebu Creek, Bayelsa State, Nigeria

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Abstract
This study investigated the toxic effects of *Raphia hookeri* fruit mesocarp on Oreochromis niloticus over six months, from June to November 2022. Palm fruits and fish samples were collected from Epebu (Ogbomama) Creek and transported to the laboratory. The fish used included juveniles (2-4 cm, approximately 5 g) and adults (8-10 cm, averaging 90 g). Four test tanks and one control tank were established for the experiment. *R. hookeri* fruits were peeled, and the mesocarp was sun-dried for 10 hours, with 20 g used for chemical analysis. The remaining dried mesocarp was powdered, with 80 g macerated in 400 ml hexane at room temperature for 24 hours. The mixture was filtered and the hexane extract was concentrated using a rotary evaporator at 40°C. The extracted oil was stored at 4°C for further analysis, while the solid fraction was dried at 50°C for proximate composition analysis. The toxicity of the extract was tested on *O. niloticus* at a concentration of 5 g/l over 48 hours. The analysis of dead fish revealed proximate composition: water (61.15±0.10%), ash (1.02±0.02%), crude fibre (7.20±0.15%), crude protein (2.72±0.04%), fats (17.02±0.11%), and carbohydrates (10.89±0.34%). Mortality rates increased with concentration: 10 mg/l resulted in 1.33±0.33 and 2.00±0.00 mortality after 24 and 48 hours, respectively; 20 mg/l led to 5.67±0.33 and 7.67±0.33; and 40 mg/l caused 8.67±0.33 and 9.67±0.33. Alanine transferase (ALT) levels increased from 10.67±0.33 in the control to 26.33±0.88 at 40 mg/l. SOD and GPX levels were elevated in exposed groups, while GSH levels decreased with higher concentrations. The study concludes that *R. hookeri* fruit mesocarp is toxic to *O. niloticus*, affecting both juveniles and adults, and is not recommended for use in sustainable fish production. No known effects on humans were observed.

Keywords: *Raphia hookeri*, *Oreochromis niloticus*, Toxicity, Mesocarp Extract, Histopathology

Introduction

Fish is an essential source of animal protein, particularly for riverine communities due to its affordability and accessibility. There is a wide variety of fish species in the wild, including tilapia, catfish, and carps. Compared to other animal proteins, fish is low in calories and easily digestible. Certain species are rich in vitamins and minerals, notably long-chain omega-3 fatty acids, iodine, vitamin D, and calcium (FAO, 2021). Omega-3 fatty acids, which have multiple health benefits, emphasise the irreplaceable nutritional value of seafood. For example, fish rich in iodine can help reduce the incidence of goitre in areas where iodised salt is unavailable (Koppe, 2017). Regular fish consumption, at least once a week, is recommended for maintaining overall health. Fish also has significant economic value. According to Deepak (2019), fisheries contribute approximately 35% of the world's animal protein. The protein content in fish is considered superior to other sources such as eggs, milk, and beef because it contains all ten essential amino acids. Fish is also an important source of minerals, including calcium, potassium, iron, and vitamins A and D. Fishing provides employment opportunities for many, particularly in coastal and riverine areas. In traditional fishing practices, the use of poisonous plants was common in Africa, although it is now largely forbidden except in remote areas. Fishermen use toxic plants to enhance their catch by suffocating fish in small, enclosed water bodies. This method involves crushing plants and introducing them into the water, which becomes anoxic, causing the fish to suffocate and rise to the surface for simple capture (Fafioye, 2005).

In southwestern Nigeria, common plants used for this purpose include Terminalia catappa, Carica papaya, Azadirachta indica, Nicotiana tobacum, Manihot esculenta, and Raphia hookeri (Fafioye, 2012). Research shows that these plants exhibit varying levels of toxicity, with Nicotiana tobacum and Manihot esculenta causing 100% fish mortality and Azadirachta indica and Carica papaya causing 90% mortality (Neuwinger, 2004). These piscicidal plants contain compounds such as alkaloids, flavonoids, glycosides, and sugars, raising

concerns about their potential adverse effects on aquatic ecosystems (Seigler, 2002; Neuwinger, 2004). Among these, Adenium obesum was reported to be the most effective. These plants are known to contain various phytochemicals such as alkaloids, tannins, saponins, and glycosides, which are toxic to fish. Piscicides have been used traditionally worldwide for fishing, but their environmental impact remains a growing concern (Neuwinger, 2004). One of the notable piscicides used by rural communities is the fruit mesocarp of Raphia hookeri, a tropical palm found in the Niger Delta region. The fruit of this palm is also used for medicinal purposes, such as treating stomach ailments and as a laxative (Liu, 2004). In addition to its use in fishing, the raffia palm has a wide range of applications: its trunk is used for firewood and construction materials, its sap is fermented to produce palm wine, and its leaves are used for thatching roofs (Obahiagbon, 2009). The fibre from the raffia palm is soft yet durable, making it ideal for crafting household materials such as mats, baskets, and hammocks. Furthermore, the succulent larvae of beetles found in infected raffia palms are considered a delicacy in some regions. The fruit pulp is also used in soap-making and paper production (Obahiagbon, 2009). However, raw raffia palm fruits are toxic and are traditionally crushed and used as fish poison (Esiegbuya et al., 2013).

Tilapias, primarily freshwater fish, inhabit shallow streams, ponds, rivers, and lakes, with fewer populations found in brackish waters. The Nile Tilapia (Oreochromis niloticus) remains the most widely farmed species of tilapia in Africa. Juvenile tilapia are omnivorous, feeding mainly on zooplankton and zoobenthos while also ingesting detritus and phytoplankton. Feeding occurs during the day, with digestion primarily happening at night. Notably, the digestive tract of Nile tilapia is at least six times the length of the fish itself (FAO, 2021; Bob-Manuel, 2017). Several studies have investigated the toxic effects of Raphia hookeri fruit in facilitating easy fish capture, primarily focusing on the cultured species Clarias gariepinus. However, limited research exists on the toxic effects of Raphia fruit on wild fish [‘[‘species, including the lethal concentration (LC50) and its impacts on various organs such as the lungs, liver, respiratory, and nervous systems. Furthermore, there is a need to understand how the use of Raphia hookeri mesocarp extract affects the nutritional value of the fish it is used to catch. Ogbuagu (2008) identified the presence of phytochemicals in Raphia hookeri, such as alkaloids, saponins, flavonoids, and phenols, along with vitamins A and E. The pulp of the fruit showed higher concentrations of vitamin E (1.04 mg/100 g), niacin (0.2 mg/100 g), alkaloid (5 g/kg), saponins (3.6 g/kg), flavonoid (4 g/kg), and phenols (4.1 g/kg), compared to the seed, which had higher levels of vitamin A (0.16 mg/100 g) and riboflavin (0.07 mg/100 g). Additionally, Akpan and Usoh (2004) reported the presence of tannins, flavonoids, saponins, polyphenols, alkaloids, cardiac glycosides, cyanogenic glycosides, deoxy sugars, and reducing sugars in the root of Raphia hookeri.

Ogbuagu (2008) also conducted an analysis of the toxic metal composition in the pulp of Raphia fruit, identifying the presence of lead (0.03 µg/g), mercury (0.04 µg/g), arsenic (0.23 µg/g), cadmium (0.04 µg/g), thiamine (0.07 mg/100 g), nitrates (3.05 mg/100 g), and nitrites (0.29 mg/100 g) in both the mesocarp and seeds. The study suggested that the primary active ingredient responsible for fish poisoning is water-soluble saponins. Nitrites, which are also found in mesocarp, are toxic to fish. The fatty substances in the mesocarp contain saponins, a potent ichthyotoxin used to immobilise fish (Ogbuagu, 2008). In another study, Elijah et al. (2005) investigated the effects of Raphia palm mesocarp on the hemological properties of African catfish, showing that increasing concentrations of Raphia extract led to a decrease in red blood cells, eosinophils, and monocytes. Water quality analysis corroborated these haematological findings, showing an increase in alkalinity and pH and a decrease in dissolved oxygen, which temporarily stupefied the fish, making them easier to catch. One artisan fisherman reported that the mesocarp extract’s toxic effect causes swelling of the fish’s intestines, likely due to the alcoholic content (ethanol) present in the Raphia palm fruit (FAO, 2021).

Materials and Methods

A completely randomised design was employed for the experiment, involving a total of 150 Oreochromis niloticus (group A: adults; group B: juveniles), with 15 fish per tank for each group. Fish samples were caught using cast or impound nets and kept alive by the fisherman. Site visits were conducted during the study period to gather accurate data on wild fish populations and Raphia palm fruit harvesting. Additional information on Raphia palm fruit processing was obtained from local fishermen. Fish specimens were placed in transparent plastic buckets filled halfway with tap water and allowed to acclimatise in the laboratory. Water in the buckets was changed daily to avoid contamination from fish exudates and maintain adequate oxygen levels. Ripe Raphia hookeri fruits were harvested from freshwater swamp forests and creeks in Epebu Village, Ogbia Local Government Area, Bayelsa State, Nigeria. The fruits were kept in the laboratory for three days to allow for full ripening and easy detachment from the bunch. After ripening, the fruits were manually detached and mechanically crushed for experimental use. In the laboratory, the length and weight of the fish samples were recorded before the experiment. A total of 150 juvenile and adult fish were used, with 75 juveniles averaging 5 cm in length and 7 g in weight and 75 adults averaging 15 cm in length and 25 g in weight. Fish were divided

into groups and placed in 3 replicates of 5 troughs each, including a control tank. Five serial dilutions of the Raphia hookeri mesocarp aqueous solution were introduced into the setups and replicates. Observations and readings were taken hourly over a 24-hour period. Group A consisted of adult fish exposed to lethal doses of blended Raphia hookeri mesocarp (raw Raphia) in an aqueous solution. Group B consisted of juvenile fish exposed to the same lethal dose. Surviving fish were removed using a hand net, and blood samples were collected for serology tests. The proximate composition of the raffia palm fruit was analysed by first isolating and drying the pulp (mesocarp) under sunlight for 10 hours. The oil was extracted from the dried pulp using the maceration method as described by Womeni et al. (2016). A total of 80 g of the dried pulp was macerated in 400 ml of hexane at room temperature for 24 hours with constant shaking. The mixture was then filtered using Whatman paper, and the filtrate was concentrated using a rotary evaporator at 40°C. The extracted oil was stored at 4°C for further analysis, while the remaining solid fraction was dried in an oven at 50°C for proximate composition analysis. To assess the toxic effects of R. hookeri mesocarp, a concentration of 5 g/l of the extract was used to determine the 48-hour toxicity of Oreochromis niloticus. The behaviour of the fish exposed to the fruit mesocarp extract was monitored for adverse effects. To evaluate the impact of R. hookeri extract on the nutritional value of the fish, proximate composition analysis was conducted both before and after exposure. The proximate analysis of the fish was performed using the standard methods outlined by the Association of Official Analytical Chemists (AOAC), with mineral content determined by atomic absorption spectrometry. The moisture content of the fish was determined using the oven-drying method (AOAC, 2006). Fish samples were washed, and non-edible portions (head, skin, fins, viscera, bones) were removed. The edible muscle portions were minced and dried at 100–105°C for 5–6 hours. The moisture content was calculated as the difference between the wet and dry weights of the sample. Moisture content = wet weight of sample−dry weight of sample Weight of the sample×100 Texture content} = \frac{\text{Wet weight of sample} - \text{Dry weight of sample}}{\text{Weight of the sample}} \times 100 Moisture content equals the weight of the sample. Wet weight of sample− Dry weight of sample ×100 The protein content of the fish was measured using the Kjeldahl method. A minced fish muscle sample was digested using sulphuric acid and potassium sulphate, then distilled and titrated with hydrochloric acid (HCl) to determine nitrogen content. The protein content was calculated by multiplying the nitrogen content by 6.25. Protein content (%)=(S−B)×N×14.007×CA×W×100\text{Protein content (\%)} = \frac{(S - B) \times N \times 14.007 \times C}{A \times W} \times 100 Protein content (%)=A×W(S−B)×N×14.007×C×100. Where: S = Titration reading for sample, B = Titration reading for blank, N = Strength of HCl (0.01N), C = volume of digestion, A = aliquot of digest taken, and W = weight of the sample. The ash content of the fish muscle was determined using the gravimetric method (AOAC). A 5 g sample of raw fish muscle was combusted in a muffle furnace at 550 °C for 16 hours. The ash content was calculated as the difference in weight before and after combustion. Ash content (%)=A−BC×100\text{Ash content (\%)} = \frac{A - B}{C} \times 100 Ash content (%)=CA−B×100. Where: A = weight of the crucible with raw sample, B = Weight of crucible with the combusted sample, and C = weight of the sample. The lipid content was determined using the method by Folch et al. (1957). A 5 g sample of fish muscle was homogenised with a chloroform-methanol mixture (2:1) and filtered. After overnight separation with calcium chloride, the lipid content was measured as the difference in weight after drying. Lipid content (%) = Final weight−Initial weight Weight of sample×100 \text{Lipid content (%)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Weight of sample}} \times 100 Lipid content (%) = sample weight Final weight− Initial weight×100. Histopathological examinations of the liver and gills were conducted before and after exposure to the raffia palm fruit mesocarp. At the end of the experiment, the fish were sacrificed, and their liver and gill tissues were fixed in 10% formalin, sectioned, and stained with haematoxylin and eosin for microscopic analysis. Statistical analysis was performed using descriptive statistics, including mean, standard deviation/error, and ANOVA ($P < 0.05$).

Results

The proximate composition of *R. hookeri* mesocarp revealed that it contains 61.15±0.10% moisture, 1.02±0.02% ash, 7.20±0.15% crude fibre, 2.72±0.04% crude protein, 17.02±0.11% fats (lipids), and 10.89±0.34% carbohydrates. These findings highlight the nutrient composition of the raffia palm fruit and its potential impact on fish exposed to its mesocarp extract.

Table 1: Proximate composition of the raffia palm fruit.

Group	*R. hookeri* fruit
Moisture	61.15±0.10
Ash	1.02±0.02
Crude fibre	7.20±0.15
Crude protein	2.72±0.04
Lipid	17.02±0.11
Carbohydrate	10.89±0.34

Cytotoxicity of *Raphia hookeri* Fruit Mesocarp Extract on Fish

The cytotoxic effects of *Raphia hookeri* fruit mesocarp extract on *Oreochromis niloticus* were evaluated by estimating the mortality rate over a period of 24 to 48 hours. The control group, which was not exposed to *R. hookeri* fruit extract, recorded no mortality throughout the 24-48 hours of the study. However, different mortality rates were observed in the groups exposed to varying concentrations of the extract. In the group exposed to 10 mg/L of R. hookeri fruit extract, the mortality rate was 1.33± 0.33 at 24 hours and increased to 2.00± 0.00 at 48 hours. For the group exposed to 20 mg/L, the mortality rates were 5.67 ± 0.33 at 24 hours and 7.67 ± 0.33 at 48 hours. The highest mortality was observed in the group treated with 40 mg/L of R. hookeri fruit extract, with rates of 8.67 ± 0.33 at 24 hours and 9.67 ± 0.33 at 48 hours (Table 4.2). These findings suggest that *R. hookeri* fruit mesocarp extract has dose-dependent cytotoxicity, with higher concentrations leading to significantly increased mortality rates in *O. niloticus*. Further studies on the specific toxic compounds within the extract are required to understand the mechanism of action leading to fish mortality.

Table 2: Mean cytotoxicity of *R. hookeri* fruit mesocarp extract on fish.

Group	Number of fish used	Mortality rate @ 24 hours	Mortality rate @ 48 hours
Control	10	0±0.00	0±0.00
Tank 10mg	10	2±0.33	2±0.00
Tank 20mg	10	6±0.33	8±0.33
Tank 40mg	10	9±0.33	10±0.33

Physiological Effects of Raphia hookeri Extract on Fish

The physiological impact of R. hookeri fruit extract on *Oreochromis niloticus* was assessed by analysing blood samples from both the control group and groups exposed to varying concentrations of the extract. Key liver integrity and oxidative stress markers, such as Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST), were evaluated. The ALT levels were lowest in the control group (10.67 ± 0.33 U/L) and highest in the group exposed to 40 mg/L of R. hookeri extract (26.33 ± 0.88 U/L). Similarly, AST levels showed a gradual increase from the control group (8.33 ± 0.33 U/L) to the treated groups, with values of 13.33 ± 0.67 U/L for 10 mg/L, 18.00 ± 0.58 U/L for 20 mg/L, and 26.33 ± 0.88 U/L for 40 mg/L of extract. These results were statistically significant at $p < 0.05$, indicating a clear dose-dependent effect of the extract on liver enzyme activity. Alkaline phosphatase (ALP) also exhibited a similar trend, with the highest value recorded in the 40 mg/L group (199.00 ± 2.89 U/L). In contrast, total protein (TP) levels decreased progressively as the extract concentration increased. The control group had the highest TP value (79.00 ± 0.58 g/L), while the values for the 10 mg/L, 20 mg/L, and 40 mg/L groups were 61.33 ± 1.33 g/L, 56.67 ± 0.88 g/L, and 54.33 ± 1.86 g/L, respectively. Total bilirubin levels also increased in the exposed groups, with values of 12.06 ± 0.04 mg/dL for 10 mg/L, 13.20 ± 0.02 mg/dL for 20 mg/L, and 17.24 ± 0.12 mg/dL for 40 mg/L compared to 7.72 ± 0.14 mg/dL in the control group. Oxidative stress markers, including superoxide dismutase (SOD), glutathione peroxidase (GPX), and reduced glutathione (GSH), were also measured. SOD and GPX levels increased progressively in the treated groups, with SOD values of 13,514.00± 65.20 uL, 16,391.33± 16.25 uL, and 23,430.33± 58.86 uL for 10, 20, and 40 mg/L treatments, respectively. GPX levels similarly rose, from 20.71 ± 0.03 U/mL in the 10 mg/L group to 29.97 ± 0.03 U/mL in the 40 mg/L group. In contrast, GSH levels decreased progressively from 680.67 ± 2.73 U/mL in the 10 mg/L group to 344.67 ± 2.85 U/mL in the 40 mg/L

group (Table 3). These findings suggest that R. hookeri extract induces significant oxidative stress and affects liver function in *O. niloticus*, with higher concentrations resulting in more pronounced physiological effects.

Table 3: Physiological effect of *Raphia hookeri* fruit mesocarp on fish.

Group	ALT	AST	ALP	TP	TBIL	SOD	GSH	GPX
Control mg	10.67±0.33	8.33±0.33	118.33±2.03	79.00±0.58	7.72±0.14	10270.67±85.11	747.33±9.82	19.00±0.03
Tank 10mg	13.33±0.67	11.33±0.33	140.33±1.33	61.33±1.33	12.06±0.04	13514.00±65.20	680.67±2.73	20.71±0.03
Tank 20mg	18.00±0.58	17.67±1.20	182.33±1.45	56.67±0.88	13.20±0.02	16391.33±16.25	535.67±2.60	24.25±0.05
Tank 40mg	26.33±0.88	29.33±1.20	199.00±2.89	54.33±1.86	17.24±0.12	23430.33±58.86	344.67±2.85	29.97±0.03

Nutritional Value of Experimented Fish

The nutritional analysis of *Oreochromis niloticus* exposed to varying concentrations of Raphia hookeri extract revealed significant differences in key parameters compared to the control group. Moisture content was highest in the control group (63.53 ± 0.13%) and lowest in the group exposed to 40 mg/L of *R. hookeri* extract (44.71 ± 0.06%). The 10 mg/L and 20 mg/L exposure groups showed moisture levels of 56.99 ± 0.04% and 47.86 ± 0.21%, respectively, with all groups showing statistically significant differences ($p < 0.05$). Ash content, representing the mineral composition, was highest in the 20 mg/L exposure group (1.18 ± 0.02%) and lowest in the 10 mg/L group (0.78 ± 0.01%), also statistically significant at $p < 0.05$. Crude fibre was most abundant in the control group (1.98 ± 0.01%), while the lowest level was recorded in the 40 mg/L treatment group. In contrast, crude protein content increased with higher concentrations of the extract, with the 40 mg/L group showing the highest level (27.44 ± 0.05%) compared to the control group, which had the lowest protein content (27.32 ± 0.18%). Lipid content increased progressively across the groups, with values of 3.47 ± 0.01% in the control, 4.69 ± 0.03% in the 10 mg/L group, 5.66 ± 0.06% in the 20 mg/L group, and 6.42 ± 0.08% in the 40 mg/L treatment group (Table 4). These results indicate that exposure to *R. hookeri* extract significantly affects the nutritional composition of the fish, particularly in terms of moisture, ash, protein, and lipid content, with higher concentrations of the extract leading to greater changes.

Table 4: Evaluation of the nutritional value of the experimented fish, treated with the raffia palm fruit mesocarp (*Raphia hookeri*).

Composition	Control (0mg)	10mg	20mg	40mg
Moisture	63.53±0.13	56.99±0.04	47.86±0.21	44.71±0.06
Ash	0.83±0.02	0.78±0.01	1.18±0.02	1.11±0.01
Crude fibre	1.98±0.01	1.77±0.01	1.57±0.01	1.40±0.02
Crude protein	O. niloticus	26.84±0.04	27.32±0.03	27.44±0.05
Lipid	3.47±0.01	4.69±0.03	5.66±0.06	6.42±0.08
Carbohydrate	2.87±0.23	8.94±0.03	16.41±0.14	18.92±0.16

Discussion

Using standard biological techniques, this study evaluated the toxicological effects of Raphia hookeri fruit mesocarp on *Oreochromis niloticus*. The proximate composition analysis of the mesocarp revealed its high moisture content (61.15 ± 0.10%), significant lipid content (17.02 ± 0.11%), and moderate amounts of crude fibre (7.20 ± 0.15%) and protein (2.72 ± 0.04%). These results align with the findings of Yakubu et al. (2021), who reported that *R. hookeri* fruit contains high moisture levels and carbohydrates, with lower levels of ash, protein, and fats. Their study also noted reductions in anti-nutritional factors after processing, which may explain why the mesocarp is less harmful to fish after cooking. The mortality analysis of *O. niloticus* over 48 hours showed a clear dose-dependent effect. The control group, which was not exposed to the mesocarp extract, recorded no mortality, while mortality rates increased with the concentration of *R. hookeri* extract. Specifically, the group exposed to 10 mg/L had mortality rates of 1.33 ± 0.33 and 2.00 ± 0.00 at 24 and 48 hours, respectively, while the group treated with 40 mg/L showed the highest mortality (8.67 ± 0.33 and 9.67 ± 0.33 at 24 and 48 hours). This observation is consistent with other studies, such as Adeogun et al. (2012), who

found that methanolic extracts of R. hookeri caused gill and liver damage in *Clarias gariepinus*, similar to the physiological disruptions observed in this study. Biochemical analysis revealed significant effects on liver function and oxidative stress markers. Alanine aminotransferase (ALT) levels were lowest in the control group (10.67 ± 0.33) and highest in the 40 mg/L group (26.33 ± 0.88). Aspartate aminotransferase (AST) and alkaline phosphatase (ALP) levels also increased progressively with increasing concentrations of the extract. These results indicate potential liver damage, as corroborated by studies like Adeogun et al. (2012), who reported similar findings in catfish. Additionally, oxidative stress markers such as superoxide dismutase (SOD) and glutathione peroxidase (GPX) showed increased activity in the exposed groups, indicating oxidative damage, while glutathione (GSH) levels decreased. The nutritional composition of fish exposed to the extract also showed notable changes. Moisture content was highest in the control group (63.53 ± 0.13%) and progressively decreased with increasing concentrations of the extract. Similarly, ash content was most significant in the 20 mg/L group (1.18 ± 0.02%), while crude protein levels were highest in the 40 mg/L group (27.44 ± 0.05%). Lipid content increased with higher extract concentrations, reaching 6.42 ± 0.08% in the 40 mg/L group. These findings align with the observations of Elijah et al. (2005), who noted that increasing concentrations of *R. hookeri* mesocarp led to physiological disruptions in African catfish, including reduced red blood cell counts and other haematological effects. The use of *R. hookeri* in traditional fishing practices has been documented by Neuwinger (2004) and Idowu et al. (2020), who highlighted the piscicidal properties of certain plants, including *R. hookeri*. This suggests that the mesocarp's toxic effects could be harnessed for fish harvesting in commercial quantities. However, it is important to note that heat processing during fish preparation likely denatures these toxins, reducing their harmful effects, as no adverse effects have been reported from consuming fish caught using this method.

Conclusion

This study confirms that *Raphia hookeri* fruit mesocarp is toxic to fish, demonstrating its potential use in fish harvesting. The biochemical and nutritional impacts observed in *O. niloticus* highlight the mesocarp's toxic effects, while the lack of adverse effects in consumed fish suggests that heat processing may mitigate its toxicity.

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