Evaluation of Heavy Metal and Anti-nutritional Profile of Macrophytes Harvested as Aqua-feed Ingredient from Nwaja Stream, Rivers State, Nigeria.

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Abstract
This study was carried out to assess heavy metal concentrations and anti-nutritional profile in aquatic macrophytes harvested as aqua-feed ingredient from Nwaja stream, Rivers State, Nigeria. Metals (Cr, Cd, Cu, Fe, Mn, Ni, Pb and Zn) in macrophytes and surface water were analysed using atomic absorption spectrophotometer (Buck 200, Buck Scientific, USA) and each metal detected, was differentiated by the degree of light penetration. Anti-nutritional factors: tannin, oxalate, flavonoid, phytate, HCN and saponin were determined using standard analytical procedure in the laboratory and the macrophytes evaluated were duckweed (Lemna minor), Water lettuce (Pistia stratiotes) and water spinach (Ipomoea aquatica). Results of this study indicated there was no significant difference ($p > 0.05$) in the values of Fe, Mn, Ni, Cu and Cd in surface water, which were all within the World Health Organization permissible limit except for Cd (0.03 mg/l) that exceeded the limit. The mean Pb concentration in water samples showed significant difference ($p < 0.05$) with higher values (0.06-0.1mg/l), which was above limit with occurrence pattern as Fe > Zn > Cu >Pb > Cr > Cd > Mn > Ni. In terms of metal accumulations in macrophytes, L.minor recorded the highest in Pb (8.16 mg/kg) with significant difference ($p < 0.05$), followed by P.stratiotes (6.17 mg/kg) while I.aquatica recorded the least (4.26 mg/kg). The same pattern was also followed in Cd accumulations :2.27mg/kg, 1.84 and 1.82mg/kg respectively. This study observed the presence of all the anti-nutritional factors and heavy metals evaluated across the macrophyte samples. Therefore, strategic methods such as fermentation, soaking, extrusion and heating is required to reduce the anti-nutritional factors before using the macrophytes as aqua-feed ingredient. Also effort should be made to culture and domesticate macrophytes instead of harvesting from the wild, to avoid heavy metal contamination which could enter into the food chain and pose health risk.

Keywords: *Aquatic, Ecosystem, Health, Malevolent, Non-conventional, Risk*

INTRODUCTION

All over the world, Aquaculture is considered as a vital agricultural sub-sector of food production with positive impact in global food security and aquatic ecosystem management (Ogunji and Wuertz, 2023). Despite the geometric and unabated rise in global population, aquaculture is still viewed as an antidote to starvation, malnutrition and poverty on a global overview (Ajayi *et al.*, 2022). Recently, this sub-sector has become a major economic booster, generating job opportunities and income in many countries of Africa, of which Nigeria is not an exemption (Mulokozi *et al.*, 2020; Issa *et al.*, 2022). Globally, most countries have benefited directly from fish production either by consumption or the use of fish products for the safety of their health (Wokeh *et al.*, 2020).

Regrettably, the effective and efficient production of fish in most countries, particularly Nigeria and some other Sub-Sahara Africa nations, has been bedeviled with the incessant rise in the cost of aqua-feed, caused by higher production cost (Orose *et al*., 2024). For decades now, farmers solely relied on imported commercial feeds, which account for about 50 to 70% of the production cost in aquaculture (Ngongolo and Magendero 2022).In most cases, the non-availability and affordability of these imported feeds together with exchange rate, has remained a key obstacle of fish production in underdeveloped and developing nations like Nigeria, where farmers had depended much on imported commercial feed without the consideration of the impacts of their actions on the country's economy (Audu and Yola, 2020).
In order to salvage the burden this over dependence on foreign aqua-feeds placed on farmers, nations through their research organisations and academics are looking inward to improve on non-conventional protein sources that are readily available, affordable and environmentally friendly. Obirikorang *et al*., (2024), posited that the development of aquaculture is hinged on the formulation and production of low-cost but nutritionally balanced feed, and this can be achieved if alternatives from fish meal, soya-bean and other conventional feed ingredients that are scare, expensive and highly demanded in other sectors are given adequate attention .As a result, different studies have been on in search for alternative protein sources and one non-conventional plant source considered as a viable alternative to the conventional feed ingredients like fish meal and soya-bean, is the aquatic macrophyte.

Macrophytes are plants found within and around the aquatic ecosystem, with some being submerged while others are either floating or emerging (Zakarias *et al*.,2020). Their availability in water constitute a nuisance to the ecosystem due to their regenerating nature within a short-while (Falaye *et al*., 2022). Aquatic macrophytes are vital feed ingredients because of their viable nutritional composition in terms of crude protein, minerals, amino acid, vitamins and carbohydrate (Sandan *et al*., 2024).
Moreover, the utilization of aquatic macrophyte in aqua-feed production has not been efficient despite the nutritional composition. This is because macrophytes can absorb large quantities of metals from their surrounding aquatic ecosystem, accumulating pollutants throughout their growth period which are unaffected by temporal fluctuations and this makes them excellent indicators of heavy metals contamination in water bodies (Skorbilowicz and Sidoruk 2025).

Heavy metals pose significant threat to human health as a result of their persistent nature and potential bio-concentration as they move through the food chain (Munyai and Dalu 2023). Potentially toxic metals such as Cd, Pb, Fe, Mn, Cu, Ni, Cr and Zn are the major pollutants found in most aquatic ecosystems and the accumulation of these metals, is raising a public concern due to their bio-magnification and bio-accumulation nature (Okey-Wokeh *et al.*, 2023). Meanwhile, the exposure of feed ingredients to anthropogenic pollutants like heavy metals has repercussion on the food chain through aqua-feed and consequently, aqua-feed can become tainted with undesirable substances originating from the environment or at the point of production (Tabassum *et al*., 2024). Heavy metals found in feed can through bio-accumulation, pose severe threat to human health by disrupting normal physiological body functions (Malik and Maurya 2014).

Apart from the accumulation of toxic metals in the tissues of aquatic macrophytes, which could be traced to be an environmental factor, another limiting factor in the efficient use of macrophytes in aqua-feed that is worthy of investigating, is the presence of anti-nutritional factors.
Anti-nutritional factors are substances which either by themselves or through their metabolites interfere with feed utilisation, affect the health and act in a manner that reduce nutrient intake,

digestion and absorption (Mesele 2023). Naturally, plants synthesize certain anti-metabolites which exert a deleterious effect upon ingestion by animals and the synthesis of these chemical substances by plants are for self-defense (Gopan *et al*.,2020). Falaye *et al*, (2022), posited that most aquatic macrophytes used as feed ingredients contain high concentration of anti-nutritional factors which are likely to affect the digestibility and absorption of protein in aqua-feed.

Owing to the dearth of information on levels of potentially toxic metals and anti-nutritional factors profile of macrophytes harvested from the Niger Delta aquatic ecosystems and Port Harcourt known for oil and gas activities; this study is therefore necessitated to evaluate the heavy metals accumulation in macrophytes harvested from Nwaja Stream and also to compare the concentration of metals in macrophytes intending to be used as aqua-feed ingredient with that of surface water where it was harvested from. Furthermore, the study will examine profile of different anti-nutritional factors in macrophytes to ascertain their usability as aqua-feed ingredient for aquatic animals, and the findings from this study will be of great importance to researchers, regulatory agents and fish farmers.

MATERIALS AND METHODS

Description of Sample Area

The study location where both macrophytes and surface water samples were collected was Nwaja Stream in Port Harcourt, Rivers State, Nigeria. The stream lies between Latitude 4^o.30N to 5º00N and Longitude 6º 45E to 7º 30E. Port Harcourt is a metropolitan town that serves as the capital of Rivers State with a population of over $1.5x10^5$ people. Nwaja stream drains the fresh water from Ekinigbo-Rumuola forest passing through other Apara Communities and empties into the Diobu creek of Bonny estuary. The choice of sampling in this water body was premised on the abundance of different species of aquatic macrophytes growing in this aquatic ecosystem, which could be bio-indicators of pollutants caused by prominent industrial and commercial activities in the area.

Sample Collection

The samples of macrophytes: Water lettuce (*Pistia stratiotes*), Duckweed (*Lemna minor*) and Water spinach (*Ipomoea aquatica*) were collected from three different points within the Nwaja stream where abundance of the plants were found. Samples collected were washed with water collected from the stream to remove debris, sediment and periphyton. Thereafter, the macrophytes were preserved in polyethene bags to avoid contamination. Also, water samples were collected with the aid of plastic bottles, filtered immediately after collection using 0.5 micrometer pore sized filter and water collected in plastic bottles were preserved by adding drops of HNO_3. Both the water and macrophyte samples were properly labeled before transporting this to the laboratory for analysis.

Determination of Heavy Metals in Macrophytes and Surface Water

The determination of metals in plants was achieved by drying the sorted macrophytes at a temperature above 75ºC in an oven for 48 hours, and this was done in triplicates for the determination of Pb, Cd, Zn, Ni, Mn, Cu, Fe and Cr. About 2.5grams of oven dried macrophyte was put into a washed 250 flask and hyperchloric acid ($HClO_4$) of about 8 mililitre (ml) was added to it and then 50 mililitre (ml) of conc.HNO_3 and later 4 mililitre (ml) of conc. H_2SO_4 was finally added to the sample. Heating of the mixture started gradually for about 15 minutes and after cooling, about 45 mililitre (ml) of distilled water was added to the mixture to make up and create a medium for the metals.

Afterwards, the mixture was heated again for a minute before allowing it to cool and the mixture was then filtered with the aid of Whatman 42 filter paper into 100 mililitre(ml) pyrex volumetric flask. The analysis of heavy metals in the filtrate was done with the Atomic Absorption Spectrometer and each metal detected was differentiated by the degree of light penetration (Alagoa *et al*.,2015).

For the determination of heavy metals in the surface water samples, the analysis protocol followed the procedure described by Okey-Wokeh and Wokeh (2022).

Determination of Anti-nutritional Factors

The levels of phytate in each of the macrophyte sample was determined through phytic acid determination using the analytic procedure described by Lucas and Markaka (1975). Oxalate was determined using the procedure described by Anaemene (2020), while tannin was determined by the procedure described by (AOAC, 2005). Saponin was determined through spectrophotometric method of Brunner (1984)

Statistical Analysis

The analysis of data obtained in this study was done using one-way analysis of variance (ANOVA) and to test differences among mean when significant values are obtained at $p < 0.05$, Duncan's multiple range test was used.

RESULTS AND DISCUSSION

The present studies showed there was no significant difference ($p > 0.05$) in terms of Fe mean concentration obtained in the surface water samples of Nwaja river as shown in Table 1.This connotes that the anthropogenic sources for ferric load in the river has similar impacts in the three sample location where the samples were collected (Pasichnaya *et al*., 2020).Consequently, the values of Fe obtained in this studies for the surface water, were beyond the threshold limit of 0.3mg/L stipulated by the World Health Organization (2011) for a healthy water. The mean concentration of Fe obtained in this studies is comparable with the higher values (0.79-2.0 mg/l) of Fe previously reported in surface water around gas-flaring stations in selected areas of the Niger Delta (Bardi *et al*., 2025). The higher concentration of Fe in surface water has a corresponding effect on the accumulation of Fe in macrophytes harvested from the water medium to be used as aqua-feed ingredient. The values of Fe in *Lemna minor* were significantly higher ($p < 0.05$) compared to *Pistia stratiotes* and *Ipomoea aquatica* as shown in Table 2. Conventionally, Fe is pivotal in formation of haemoglobin being the oxygen carrier and its importance in plants cannot be overemphasized, but when it exceeds the permissible limit, it poses a health risk in the food chain (Wangboje and Ekundayo,2013).

The mean concentration of Pb showed statistical significance difference ($p<0.05$) both in surface water and macrophyte samples as presented in Tables 1&2. The findings indicated highest Pb value in location (P1) and *Lemna minor* when compared with others. The higher load of Pb in surface water could be attributed to anthropogenic activities within and around the aquatic ecosystem, which may have given the corresponding effect on bio-accumulation of Pb by the macrophytes. The results depicted the mean concentration of Pb exceeded the permissible value established by the World Health Organization. Previous studies by (Okey-Wokeh *et al.,* 2023), reported similar Pb mean value of 0.20 mg/l in Ogbor river, Niger Delta region of Nigeria and it was attributed to the impacts of anthropogenic activities. Additionally, Uddin *et al.,* (2021), reported bio-accumulation of Pb by aquatic macrophytes like *Ipomoea aquatica* being high in concentration. Studies have shown that Pb is a toxic metal with no health benefit, and its entrance into the body via food or water can cause plumbism, disrupt brain, liver, kidney and reproductive organs (Isah *et al*., 2021).

The mean concentrations of Cu in surface water samples ranged between 0.34-0.41mg/l with observable significant difference ($p < 0.05$) in both water and macrophyte samples. The values of Cu observed in this study were below permissible limit established by the World Health Organisation. The low Cu values recorded in the surface water samples of this study, aligned with 0.01-0.31 mg/L reported by Okey-Wokeh *et al* (2023) in Ogbor river surface water, while the mean concentration of Cu observed in macrophytes were below values (5-7mg/kg) previously reported by Alagoa *et al.,*(2015) in macrophytes from Aba river. Normally, Cu is an essential metal supportive in plant metabolism, but accumulation of Cu in higher concentration above the threshold will cause disruption of biochemical and physiological functions in plants (Kumar e*t al*., 2012), while the values of Cu above 30 mg/kg in fish or mammals could result to liver cirrhosis, necrosis in kidney and low blood pressure (Isah *et al*., 2021).

The mean Cd concentration in surface water samples showed no significant difference ($p>0.05$) from each other, while the values observed in macrophytes, showed that the mean concentration in *Lemna minor* was the highest with observable significant difference ($p < 0.05$) from *Pistia stratiote*s and *Ipomoea aquatica.* The mean concentration of Cd observed in this study is above the permissible limit. Similarly, previous studies by Okey-Wokeh *et al.,* (2023) in Ogbor river, reported values above 0.003 mg/l. Cadmium does not degrade easily to less toxic product in the environment, and this contributes to its bio-accumulation. The elevated values in water may have resulted to a corresponding effect on the accumulation of Cd in macrophytes and this could be attributed to the influence of industrial operation around Nwaja river. The Cd observed in aquatic macrophytes is comparable with the value previously reported by Al-Abbawy *et al.,* (2020) on assessment of some heavy metals in various aquatic plants and they found that Cd concentration obtained was above 0.02 mg/kg the permissible limit. The entrance of Cd into the food chain will be toxic to fish and other aquatic organisms since it can have the ability to spread carcinogenic effects in humans (Davies *et al*., 2023).

The results of this study revealed Zn and Ni mean concentrations in both water and aquatic macrophytes were within the international safety threshold. The values of Zn showed statistical significance difference ($p <0.05$)in both water and macrophytes, while Ni concentration showed no significant difference ($p > 0.05$). Zinc is an essential metal but its elevation above allowable limit in water or plant will be inimical to both aquatic organism and man. Also, the concentration of Ni observed in macrophytes were below 10 mg/kg previously reported by Al-Abbawy *et al* (2020) as W.H.O permissible limit.

Additionally, the mean concentration of Cr in water samples indicated there was no significant difference ($p > 0.05$) across the surface water samples, while the mean concentration of Cr in macrophytes depicts there was significant difference ($p < 0.05$) with higher mean value in *Lemna minor* and *Ipomoea aquatica*, compared to *Pistia stratiotes* with the least concentration. The mean Cr concentration observed in this study in both water and macrophytes is within the permissible limit. Similarly, Okey-Wokeh and Wokeh (2022) had previously reported low Cr concentration in surface water of Mini-Ezi stream, Elele-Alimini. The corresponding low Cr in macrophytes, aligns with the findings previously reported by Alagoa *et al* (2015) for macrophytes harvested from Aba River. Chromium (Cr) is known as an essential nutrient for both aquatic life and human, but excessive accumulation of Cr beyond the safety level, can pose significant health and environmental risks (Tabassum *et al*., 2024).

The mean concentration of Mn showed no statistical significant difference ($p > 0.05$) in both water and the macrophytes. The mean concentrations of Mn in both water and macrophytes were lower than 0.05mg/l stipulated as standard limit for water by the World Health Organisation (2011). Mn is an essential element for all living organisms since it functions as a co-factor in a number of enzymes and its demand in living cells makes it low in availability (Wokeh *et al.,* 2023).

Table 1: Mean Concentration of Heavy Metals Present in Surface Water Samples Collected from Locations where Macrophytes Samples were Harvested.

	Parameters (mg/L)	P_1	P_2	P_3	WHO
1	**Fe**	2.84 ± 0.30^{a}	2.93 ± 0.34^{a}	2.89 ± 0.40^{a}	0.3000
2	**Pb**	0.10 ± 0.08^{a}	0.08 ± 0.03^{b}	0.06 ± 0.03^{c}	0.010
3	**Cu**	0.39 ± 0.03^{a}	0.42 ± 0.03^{a}	0.41 ± 0.03^{a}	1.000
4	**Cd**	0.03 ± 0.01^{a}	0.03 ± 0.01^{a}	0.03 ± 0.02^{a}	0.003
5	**Zn**	0.57 ± 0.50^{a}	0.17 ± 0.13^{b}	0.18 ± 0.14^{b}	5.000
6	**Ni**	0.01 ± 0.00^{a}	0.02 ± 0.00^{a}	0.01 ± 0.00^{a}	0.020
7	**Cr**	0.06 ± 0.03^{a}	0.06 ± 0.02^{a}	0.05 ± 0.02^{ab}	0.050
8	**Mn**	0.02 ± 0.01^{a}	0.01 ± 0.02^{ab}	0.02 ± 0.01^{a}	0.050

In each row, mean with a common letter are not significantly different ($p > 0.05$)

Table 2: Mean Concentration of Heavy Metal Accumulation in some Macrophytes Harvested from Nwaja River.

	Parameters (mg/kg)	Duckweed	Lettuce	Water Spinach
1	**Fe**	12.7 ± 6.20^{a}	10.62 ± 6.22^{b}	10.11 ± 6.20^{b}
2	**Pb**	8.16 ± 0.90^{a}	6.71 ± 0.82^{b}	4.26 ± 0.80^{c}
3	**Cu**	3.94 ± 0.24^{a}	3.06 ± 0.254^{b}	2.98 ± 0.24^{c}
4	**Cd**	2.27 ± 0.04^{a}	1.84 ± 0.04^{b}	1.82 ± 0.04^{b}
5	**Zn**	8.78 ± 0.12^{b}	8.17 ± 0.04^{c}	8.94 ± 0.18^{a}
6	**Ni**	1.28 ± 0.25^{a}	1.27 ± 0.25^{a}	1.28 ± 0.25^{a}
7	**Cr**	4.42 ± 0.22^{a}	3.51 ± 0.22^{b}	4.04 ± 0.22^{ab}
8	**Mn**	1.21 ± 0.07^{a}	1.25 ± 0.07^{a}	1.26 ± 0.07^{a}

In each row, mean with a common letter are not significantly different ($p > 0.05$)

Table 3 shows the composition of Anti-Nutritional Factors in Macrophytes harvested from Nwaja Stream. The results as shown in Table 3 revealed the presence of tannin in all the macrophytes with the highest mean value observed in *Lemna minor*, followed by *Ipomoea aquatica*, while *Pistia stratiotes* recorded the least tannin mean concentration. Statistically, these values showed significant difference ($p < 0.05$) from each other. Generally, the tannin concentration in all the macrophytes in this study were higher than the value (0.56) previously reported by Suleiman *et al* (2020) in *Eichhnornia crassipes* grass. Tannin is known to be responsible in depleted feed intake, protein digestibility and feed efficiency, which consequently affects the growth rate of experimental animals (Vikram *et al*., 2020). The higher concentration of tannin as observed in this study is capable of affecting feed palatability, protein utilisation, microbial enzyme activity and intestinal digestion.

The overall results of anti-nutritional factors in the different macrophyte samples revealed *Pistia stratiotes* had the highest value of phytate with observable significant difference ($p < 0.05$) across the macrophyte samples. Sandan *et al.,* (2024), previously reported a higher concentration (2.10) in *Ipomoea aquatic*a and (1.85) in *Pistia stratiotes* against other macrophytes with lower phytic acid values. Phytates or Phytic acids occur naturally in the plant at different levels, ranging from 0.1- 6.0% and the presence hinders enzymatic activity that are necessary for protein degradation in small intestine and bio-availability of essential minerals (Samtiya *et al.*, 2020).

In this study, saponin concentration was highest in *Pistia stratiotes,* followed by *Ipomoea aquatica,* while *Lemna mino*r was the lowest mean concentration as presented in Table 3. The mean values of Sponin in all the macrophyte samples were significantly different ($p < 0.05$) from each other. These values are in consonant with the value (0.72) mean concentration of Saponin previously reported by Falaye *et al* (2022) in raw duckweed. Saponin is known to be toxic to fish and other cold-blooded animals, and in higher concentration, it impacts a bitter taste, impair growth and inhibits enzymatic activity as well as protein digestion (Mesele, 2023).

The values of hydrogen cyanide (HCN) in the macrophyte samples as shown in Table 3, revealed there were higher composition of HCN in Water Lettuce (*Pistia stratiotes*) and Duckweed (*Lemna mino*r), which showed no significant variations from each other but were significantly different from the HCN composition in Water Spinach (*Ipomoea aquatica*) that had the least mean value. The values of HCN observed in *Lemna minor* and *Pistia stratiotes* are similar with the HCN value (4.88 mg/100g) Falaye *et al.,* (2022) reported from their study on the effects of processing on Duckweed as fish feedstuff. Hydrogen Cyanide (HCN) also known as Prussic acid, is one of the most common anti-nutritional factors in plants which exist in form of Cyanogenic glycosides or Cyanogen (Gopan *et al*., 2020). Cyanides can inhibit respiration, cause cardiac arrest and alter glucose metabolism in experimental animals.

The values of flavonoid observed in macrophytes in this study, showed higher significant variation ($p < 0.05$) in *Lemna minor* compared to *Pistia stratiotes* and *Ipomoea aquatic*a that showed no significance difference ($p > 0.05$) from each other. This result is in consonant with the previous report of Chandrakala *et al.,* (2015), that the flavonoid concentration in *Eichhnornia crassipes* ranged from 31.2-39, while *Pistia stratiotes* was 12.3-19.5%. Higher concentration of flavonoid limits the absorption of essential elements like Fe and Zn, and also inhibits digestive enzymes in animals (Vikram *et al*., 2020).

The mean concentration of oxalate across the macrophyte samples indicated there was significant variation ($p < 0.05$) with Water Lettuce (*Pistia stratiotes*) that recorded the highest value, followed by Duckweed *(Lemna mino*r), while Water Spinach (*Ipomoea aquatica*) had the lowest value. The values of Oxalate observed in this study, is comparable with the (4.06%) composition of oxalate previously reported by Suleiman *et al* (2020) in Water Hyacinth (*Eichhnoria crassipes*). The presence of oxalate in higher level in a feed, when consumed can result to muscular weakness, paralysis, gastrointestinal tract irritation and nephrotic lesions in kidneys of the experimental animals (Vikram *et al*., 2020).

Table 3: Mean Concentration of Anti-Nutritional Factors in Different Macrophytes Harvested for Feed Ingredient.

	Parameters (mg/100 Dw)	Duckweed	Lettuce	Water Spinach
1	**Tannin**	9.75 ± 0.16^{a}	6.98 ± 0.09^{c}	8.79 ± 0.11^{b}
2	**Phytate**	1.27 ± 0.02^{c}	5.08 ± 0.07^{a}	3.27 ± 0.01^{b}
3	**Saponin**	0.42 ± 0.05^{c}	0.75 ± 0.10^{a}	$0.5\ 1 \pm 0.08^{b}$
4	**HCN**	4.20 ± 0.01^{a}	5.00 ± 0.01^{a}	1.10 ± 0.00^{b}
5	**Flavonoid**	34.49 ± 11.2^{a}	21.21 ± 1.30^{b}	22.52 ± 1.5^{b}
6	**Oxalate**	4.21 ± 0.02^{b}	6.01 ± 0.04^{a}	2.77 ± 0.01^{c}

In each row, mean with a common letter are not significantly different ($p > 0.05$)

CONCLUSION

In recent time, aquatic macrophytes have received unusual research attention as alternative plant protein source due to their nutritional viability. Despite the nutritional potency, macrophytes such *Lemna mino*r, *Ipomoea aquatica* and *Pistia stratiotes* have been observed to contain higher anti-nutritional factors like flavonoid, oxalate, tannin saponin, phytate and HCN, and these make the usability of these macrophytes difficulty as ingredient in aqua-feed production. The abundant composition of anti-nutritional factors in macrophyte samples as observed in this study, will inhibit the utilisation of protein, essential minerals and possibly cause gastrointestinal tract problem for the experimental animals should strategic measures such as extrusion, heating or boiling, fermentation and soaking of the raw macrophytes is not taken to reduce the anti-nutritional composition of the macrophytes. Also, it is importance to be abreast with the anti-nutritional composition of any macrophyte intended to serve as aqua-feed ingredient, as that will help to know the best method to reduce the anti-nutritional factors for efficient utilisation of the nutrients.

Finally, this study observed the accumulation of heavy metals in all the macrophytes harvested from the stream and when compared with the concentrations of heavy metals in the surface water, it was concluded that the presence of metals in the surface water had corresponding effect on the macrophytes. Therefore, it is important to note that macrophytes have the ability to accumulate heavy metals from water medium and when used as aqua-feed ingredient, the toxic metal in them could enter into the food chain, thereby causing health risk. In order to avoid the risk of transferring the malevolent effects of toxic metals through microphytes as feed ingredient to the fish and humans, the domestication and culture of macrophytes in an environment free of pollution and contamination should be encouraged for efficient and sustainable feed production.

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