CONTRIBUTORY IMPACT OF SEWAGE ON POLLUTED OGUN AND LAGOS FISHING WATERS: INFLUENCE ON ANTIOXIDANT PROFILE AND PROXIMATE COMPOSITION OF SILVER CATFISH (*Chrysichthys nigrodigitatus*)

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ABSTRACT

Water pollution, a recurring phenomenon in fishing waters of industrial cities in Nigeria, inadvertently constitute hazards to the host biotic communities and the ecosystem. To continuously delineate the impacts of pollution via sewage outlets on aquatic life, this rainy season study investigated *Chrysichthys nigrodigitatus*, an aquatic food from Ogun River and Epe Lagoon, Nigeria, both of which are locally channeled for sewage release. Sixty (60) samples of *C. nigrodigitatus* were collected from six sites each representing a group (n=10), with mean weight and length of 762.2 ± 11.05 g and 42.21 ± 0.30 cm respectively. Ajegunle (control), Alaapa and Quarry (test sites) along the Ogun River course in Abeokuta; Ebute-Alashe (control), Oluwo and Marina (test sites) along the Epe Lagoon. Analysis of Biochemical Oxygen Demand and Chemical Oxygen Demand showed elevated variations at the sampled test sites than the control sites and above WHO safe limits. Significant (p < 0.05) increases in concentrations of heavy metals (lead, arsenic and cadmium) in the fishing waters from the sampled test locations particularly the Quarry and Marina sites, as well as in blood samples of fish, were observed when compared with their respective controls. Antioxidants profiling showed significant increases (p < 0.05) in superoxide dismutase and catalase activities in fishes from Alaapa (14- and 3-fold), Quarry (8- and 4-fold), Oluwo (9- and 3-fold) and Marina (8- and 4-fold) sites, while significant increases in glutathione-S-transferase activity were observed only in fishes from Quarry (5-fold) and Marina (4-fold) sites respectively. The glutathione concentration significantly decreased in fishes from all the test sites while malondialdehyde concentrations significantly increased in fishes from all the test sites compared with the respective controls. Proximate analysis of the fish samples showed significant increases (p < 0.05) in moisture and fiber contents, but significant decrease in fat, ash and protein contents compared with the respective controls. The results of the study showed that sewage pollution of fishing waters is hazardous to aquatic life as it induces oxidative stress and significantly reduces the nutritional value of the fishes obtained from such water bodies.

Keywords: Sewage, Oxidative stress. Proximate composition, *Chrysichthys nigrodigitatus*, Ogun River, Epe Lagoon.

INTRODUCTION

Water is one of the natural resources that can be managed, diverted, transported, stored, and recycled which makes it a great utility for human beings [1]. Renewable freshwater is beneficial to humans as it can serve as a source of water for drinking, industrial use, irrigation, fish production, recreation, waste disposal and transportation [2]. Water quality is a primary principle that serves as a groundwork for the health and sustenance of aquatic bodies and hydrology [3]. The pollution of waterbodies which results in a reduction in their quality, is a major factor contributing to the scarcity of freshwater all over the world [4]. Anthropogenic
activities like extensive industrialization, urbanization, population expansion, and agricultural practices have caused the deterioration of water quality in several parts of the world [5]. Anthropogenic heavy metal can enter the aquatic environment through sewages, automobile emissions, mining, industrial effluents, metallurgy and agricultural production.

The indiscriminate release of industrial effluents, domestic sewages, municipal wastes and agricultural run-offs into waterbodies lead to bioaccumulation of heavy metals and other toxicities in aquatic environments with consequential detrimental impacts on public health and biodiversity [15].

Fish consumption has increased greatly recently due to the nutritional and health benefits they possess and being the cheapest source of animal protein [6]. In addition to its importance as a source of protein, fish have rich contents of vitamins, essential minerals and unsaturated fatty acids [6]. However, fishes obtained from contaminated rivers pose serious health risks to man through bioaccumulation and bioconcentration of ingested pollutants via the food chain [7].

Aquatic ecosystems have become polluted with inorganic pollutants such as heavy metals which exerts severe toxic effects because of their toxicokinetics, bioaccumulation, and biomagnification by aquatic organisms, most especially fishes [8]. To ameliorate the toxic effects, the organisms have developed several enzymatic and non-enzymatic antioxidant defenses for scavenging free radicals generated within cells [9]. Antioxidant enzymes and the oxidative stress biomarkers, as well as lipid peroxidation, are considered as the most important biomarkers used to identify polluted waters [10]. Antioxidant defence system in aquatic lives may be impaired as a result of accumulated organic and inorganic pollutants that participates in reactive oxygen species (ROS) generation reactions in tissues, which consequently distorts pro-oxidant/antioxidant balance [11]. When antioxidant defence mechanisms are impaired or overwhelmed, oxidative stress occurs leading to deleterious consequences which may include damage to cellular macromolecules (DNA, RNA, proteins etc.), enzymatic inactivation and peroxidation of cell constituents [11].

Ogun River and Epe Lagoon, located in Ogun and Lagos states, the industrial hubs of Nigeria, are waters depended on by humans living within their proximities for their livelihood, and has recently been of particular interest and concern owing to the continual release of untreated wastes from local industries and indiscriminate disposal of sewage wastewaters into the fishing waters, leaving the river polluted with numerous toxicants most especially heavy metals [12].

*Chrysichthys nigrodigitatus*, also known as silver catfish, is a silver coloured catfish commonly found in Ogun River and Epe Lagoon, Nigeria and other West African countries. It is a highly valued fish among the indigenous populations found in Africa as it has been observed to be a type of fish that does not have a strict feeding habit [13], and considered to be an omnivorous animal because it has the ability to ingest just any food material it finds in its environment [14]. The imminent diminishing quality of Ogun River and Epe Lagoon fishing waters due to pollution by sewage over the years may exert a debilitating effect on the quality and value of aquatic
organisms especially fishes. In this study, antioxidant profiles, heavy metal concentration and the nutritional composition of *C. nigrodigitatus*, were evaluated in order to unravel the detrimental effects of sewage population on aquatic life.

**MATERIALS AND METHODS**

**Chemicals and reagents**

Glutathione, 1- chloro-2,4, dinitrobenzene, 5,5’-dithiobis (2-nitrobenzoic acid), hydrogen peroxide, and thiobarbituric acid were products from Sigma chemicals, USA and Randox kit was procured from Randox laboratories-US limited, USA. All chemicals and reagents used in the study were pure and of analytical grade.

**Study area selection and sampling**

Ogun River and Epe Lagoon serve as major sources of water for those inhabitants of Abeokuta, Ogun state and Epe, Lagos state respectively, and other villages situated along their banks. The Ogun River and Epe Lagoon are used for many purposes such as agriculture, transportation, fishing, industrial activities, refuse dumpsite, farm irrigation, drinking and other domestic purposes. Along their watercourse, Ogun River and Epe Lagoon constantly receive effluents from abattoirs, saw mills, breweries, dyeing industries, sewages, refuse, fish carcasses and domestic and industrial wastewaters. The sampled sites were selected based on evident human and industrial activities. The sites were marked with the aid of a global positioning system (GPS) and the coordinates of the sites were recorded.

Ogun River is one of the major rivers in the south-western part of Nigeria having coordinates of 3°28’E and 8°41’N with a total area of 22.4 km$^2$ [15]. It flows from Shaki, Oyo State through Abeokuta, Ogun State [7]. Two sewage-polluted sites (Alaapa and Quarry) and the control site (Ajegunle) along the Ogun River watercourse were selected and sampled during the rainy season (June to July, 2019).

Epe Lagoon is one of the fishing waters located in Lagos state, Nigeria having coordinates between longitudes 6°33.710´N, 4°03´710´ E and latitudes 6°31.893’ N, 3°31.912´ E. It has a surface area of about 243 km$^2$ and a maximum depth of about 2.8 m [16]. The Epe Lagoon is sandwiched between two (2) lagoons; Lekki lagoon (freshwater) and Lagos lagoon (brackish). Epe Lagoon connects to the sea via the Lagos harbor [17]. Two sewage-polluted sites (Oluwo and Marina) and the control site (Ebute-Alashe) along the Epe Lagoon watercourse were selected and sampled during the rainy season (June to July, 2019).

Water sampling was done following the procedure of Ndimele and Kumolu-Johnson [18]. Water samples were collected from the sampled sites in duplicates using 500 mL sampling bottles for physicochemical analysis and heavy metals analysis.

Sixty (60) samples of silver catfish (*Chrysichthys nigrodigitatus*) were collected from six sites each representing a group (n=10), with mean weight and length of 762.20 ± 11.05 g and 42.21 ± 0.30 cm respectively. Sampled sites include: Ajegunle (control), Alaapa and Quarry in Abeokuta, Ogun state, along the Ogun River; Ebute Alashe (control), Marina and Oluwo in Epe, Lagos state along the Epe Lagoon.

Fish samples were obtained from each site with the help of professional fishermen residing within the proximity of the sampled areas along the fishing waters in the morning and were transported quickly...
in a cooler box containing the sampled site water to the laboratory. The fish samples weights and full lengths were measured and recorded.

Blood samples (5 ml) were obtained from the caudal vein of each fish and immediately transferred into EDTA sample tubes which were subsequently refrigerated. Aliquots of whole blood samples were separated for heavy metal analysis as well as biochemical assays determination. The remaining blood samples were centrifuged immediately to separate the plasma for lipid peroxidation assay. Fillets were prepared from properly rinsed fish samples following beheading and gutting. Aliquots of edible tissues were taken for analysis of fish proximate composition and stored at -20°C till further analyses.

**Determination of physicochemical properties of collected water samples**

The physicochemical analyses of collected water samples were performed following standard protocols [19]. The details were well described in the earlier publication [20].

**Heavy metals analyses of fish blood and site water samples**

The concentrations of heavy metals (arsenic, lead and cadmium) in the water and in the whole blood of *C. nigrodigitatus* from the sampled sites were determined using atomic absorption spectrometry (AAS) (Perkin-Elmer 3110, USA). 1 ml of blood was digested with concentrated nitric acid and digest brought to a constant volume. Water samples were acidified with 5% nitric acid and analysed directly without further treatment. External standardization for lead was done by analyzing a certified Spex Lead Standard (Spex Industries, Inc., Edison, New Jersey, USA) along with the samples. Procedural accuracy of the lead analyses was also evaluated by spiking control samples with the Spex Lead Standard. In all cases, two determinations were made for each sample and the mean lead recovery rate of 96.64 ± 3.2% was obtained for lead for all the analyses, Onunkwor et al. [20].

**Biochemical assays of blood samples**

The whole blood activity of superoxide dismutase was determined at 420 nm according to the Li [21] modified procedure of Marklund and Marklund [22]. The whole blood catalase activity was assayed following the protocol described by Beers and Sizer [23]. Reduced glutathione concentration in whole blood was determined using the method described by Ellman [24]. Glutathione-S-transferase activity in whole blood was determined using the method described by Habig and Jakoby [25]. Lipid peroxidation in plasma was estimated following the method of Draper et al. [26].

Total protein content in fish whole blood samples was determined using Randox kits (TP 245) from Randox laboratories-US, USA.

**Proximate analysis of whole *C. nigrodigitatus* samples**

The proximate composition of the fish samples was determined using standard methods described in AOAC [27]. The details were earlier described in Onunkwor et al. [20].

**Statistical analysis**

All results were expressed as Mean ± Standard Error of Mean. Data were analyzed using one-way analysis of variance (ANOVA) followed by post-hoc Dunnett’s multiple comparisons test by Statistical Package of GraphPad prism version 7.0. Differences were considered significant at p < 0.05.
RESULTS AND DISCUSSION

Although, significant variations in the tested physicochemical parameters were observed in the water samples from some of the test sites along the Ogun River and Epe Lagoon, however, the observed pH, temperature and dissolved oxygen values of the water from all the sampled sites were within the WHO [28] permissible limit (pH = 6.5 - 8.5; Temperature ≤ 40 °C, DO ≥ 6 mg/L) (Table 1). These findings are similar to that reported by Awomeso et al. [29]. Meanwhile, the mean chemical oxygen demand values of water from all sampled test sites along Ogun River and Epe Lagoon were higher than the WHO [28] permissible limit (< 20 mg/L). The significant increase (p < 0.05) in the COD observed in the water sampled from Quarry and Marina sites along Ogun River and Epe Lagoon (Table 1) is consistent with the findings of Eruola et al. [30] who reported a significantly increased COD in polluted Lagos coastal waters in Nigeria. The total dissolved solids values observed from all sampled sites along Ogun River and Epe Lagoon were below 1000 mg/L which is within the permissible limit set by WHO [28] (Table 1). Taken together, although some of the physicochemical parameters (pH, temperature and BOD) of the sampled test sites along Ogun River and Epe Lagoon lie within the WHO [28] recommended safe limits, implying that the waters were safe for aquatic life habitation as well as for a variety of utility purposes, however, the high COD and TDS values signifies gross pollution of the waters, with inherent detrimental effects on aquatic life and the ecosystem.

Table 1. Physicochemical analysis of water sampled from Ogun River and Epe Lagoon sites

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ogun River</th>
<th>Epe Lagoon</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Alaapa</td>
</tr>
<tr>
<td>Temp. (°C)</td>
<td>26.29±0.17a</td>
<td>28.17±0.10b</td>
</tr>
<tr>
<td>pH</td>
<td>7.25±0.05b</td>
<td>7.20±0.15b</td>
</tr>
<tr>
<td>DO (mg/L)</td>
<td>10.06±0.04b</td>
<td>7.90±0.02ab</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>4.79±0.02a</td>
<td>6.22±0.02b</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>18.37±0.07a</td>
<td>20.85±0.05b</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>141.17±1.35a</td>
<td>597.32±6.10c</td>
</tr>
</tbody>
</table>
All values are expressed as mean ± SEM. Values with different superscripts are significantly different (p < 0.05) across the row.

Figure 1. Arsenic (a), lead (b) and cadmium (c) concentrations in sampled sewage-contaminated fishing waters. All values are expressed as mean ± SEM of independent triplicate measurements. Asterisks denote significant difference at p < 0.05, ns; no significant difference.

Arsenic, lead and cadmium concentrations in the water from the sampled sites are shown in figure 1a. Though the metals (As, Pb and Cd) concentrations in the water sampled from the control sites and some sites along the Ogun River and Epe Lagoon lie within the permissible limit (0.01 mg/L) of WHO [28], higher metals concentrations above the permissible limits were observed for arsenic concentration in the water sampled from Alaapa, Quarry and Marina sites, lead concentrations in samples from Quarry and Marina sites, and cadmium concentrations in samples from Quarry, Oluwo and Marina sites. A significant increase (p < 0.05) was observed in the arsenic, lead and cadmium concentrations in the water sampled from Quarry site when compared with the controls.

Figure 2 shows the concentrations of arsenic, lead and cadmium in the whole blood of Chrysichthys nigrodigitatus from the sampled sites along Ogun River and Epe Lagoon respectively. A significant increase (p < 0.05) was observed in the concentration of arsenic in the whole blood of C. nigrodigitatus sampled from all the test sites along Ogun River and Epe Lagoon while as for lead, significant increase (p < 0.05) was observed only in the blood samples from Quarry and Marina sites along Ogun River and Epe Lagoon respectively. No significant difference (p > 0.05) was observed in the lead concentrations in samples from Alaapa and Oluwo sites along Ogun River and Epe Lagoon respectively compared with the controls. There was significant increase (p < 0.05) in the cadmium concentration in the blood samples from Alaapa...
and Quarry sites along Ogun River and Marina site along Epe Lagoon while no significant difference (p < 0.05) was observed in the cadmium concentration in the whole blood of *C. nigrodigitatus* sampled from Oluwo site along Epe Lagoon compared with the controls. The elevated levels of arsenic, lead and cadmium observed in the water from the sampled test sites as well as whole blood samples of *C. nigrodigitatus* collected from the sampled test sites along Ogun River and Epe Lagoon (Figures 1 and 2) serves as direct indicators of the high rate of pollution of the waters, which could be a consequence of the channeled sewage drainages and the different anthropogenic activities taking place at and around each of the sampled sites, thus resulting in the accumulation of these heavy metals. This observation is corroborated by the findings of Lawal-Are et al. [17] and Adeosun et al. [31] where high concentrations of arsenic, lead and cadmium were observed in the water and fish from some sampled sites along Ogun River and Epe Lagoon. The high concentrations of these heavy metals observed both in the fishing waters and blood of *C. nigrodigitatus* may endanger the health of both aquatic and human lives as they become biomagnified along the food chain.

![Graph](image1)

**Figure 2.** Arsenic (a), lead (b) and cadmium (c) concentrations in blood samples of *C. nigrodigitatus* from sewage-contaminated fishing waters. All values are expressed as mean ± SEM of independent triplicate measurements. Asterisks denote significant difference at p < 0.05, ns; no significant difference.

Figure 3 shows the activities of the antioxidant enzymes in the blood samples. Superoxide dismutase and catalase activities in the whole blood samples from all the test sites showed a significant increase (p < 0.05) compared with the respective controls, along Ogun River and Epe Lagoon. In figure 3c, no significant difference (p > 0.05) was observed in the glutathione–S–transferase activity in the whole blood of *C. nigrodigitatus* sampled from Alaapa and Oluwo along Ogun River.
and Epe Lagoon respectively, while a significant increase ($p < 0.05$) was observed in the glutathione–S–transferase activity in the whole blood of *C. nigrodigitatus* sampled from Quarry and Marina sites along the Ogun River and Epe Lagoon respectively compared with the controls. Figure 4 shows the glutathione and malondialdehyde concentrations in the blood and plasma samples respectively. A significant decrease ($p < 0.05$) was observed in the glutathione concentration in the whole blood samples of *C. nigrodigitatus* sampled from all the test sites along Ogun River and Epe Lagoon compared with the respective controls, while the reverse trend was observed for malondialdehyde concentrations in the plasma samples. The assessment of oxidative damage and antioxidant defense in fishes can serve as an indicator of heavy metal contamination of the aquatic habitat as heavy metals are well known to induce oxidative stress, which result in the oxidation of lipids and proteins, alteration of gene expression, and changes in cell redox status [32]. Fishes have antioxidant defense mechanisms such as catalase, superoxide dismutase, glutathione, and glutathione-S-transferase, which protect them from the oxidative effect of heavy metals [37]. In the cell, superoxide dismutase is the first detoxification enzyme and most powerful antioxidant, as it is known to exhibit a cytoprotective ability against the damage induced by free radicals by converting superoxide radicals (O$_2^-$) generated in the peroxisomes and mitochondria to hydrogen peroxides [32, 33]. Catalase is the most sensitive enzymatic antioxidant as it secure cells from the lethal effects of hydrogen peroxide (H$_2$O$_2$) and other reactive oxygen species (ROS) [33]. Decreased levels of cellular reduced glutathione level is a potent indicator of the oxidizing state of the cell as it forms GS-metal complexes with various heavy metals through its thiol group [34]. Glutathione-S-transferase aids the protection of cells against toxicants and pollutants through the conjugation of the thiol group of glutathione to electrophilic xenobiotics, and thus defends cells against the mutagenic, carcinogenic, and toxic effects of toxicants [35]. The observed increase in the activities of superoxide dismutase, catalase and glutathione-S-transferase (Fig. 3) in the whole blood of *C. nigrodigitatus* from the sampled test sites along Ogun River and Epe Lagoon could be attributed to an increased free radical production, consequent to exposure of the fishes to elevated levels of heavy metals observed in the water from the sampled test sites, indicating the polluted state of the waters. These observations corroborates the finding of Ruas et al. [36] who reported significantly increased superoxide dismutase activity in the erythrocytes of cichlid fish from a heavy metal-contaminated river. Studies have also shown increased catalase activity in different fish species after exposure to copper (Cu) and cadmium (Cd) [37]. Earlier studies of Abdullah et al. [38], reported significantly increased activity of glutathione-S-transferase in *Channa striata* due to heavy metals and pesticides exposure. Furthermore, the significant decrease observed in the reduced glutathione concentration in the whole blood of *C. nigrodigitatus* sampled from all the test sites along Ogun River and Epe Lagoon (Fig. 4a) depicts the oxidation state of the erythrocytes as a result of exposure to heavy metals. This observation is corroborated by the findings of Eroglu et al. [39]. Malondialdehyde (MDA) is an end-product of lipid peroxidation which serves as a good oxidative stress biomarker [40]. In the present study, a significant
increase was observed in malondialdehyde concentration in the plasma of *C. nigrodigitatus* sampled from all the test sites (fig. 4b), indicating an increase in lipid peroxidation level which may be consequential of increased reactive oxygen species generation as a result of exposure to heavy metals such as arsenic, lead and cadmium, with an attendant significant decrease in glutathione concentration in the whole blood of *C. nigrodigitatus* from the sampled test sites. This observation suggests that exposure to heavy metals activates lipid peroxidation in *C. nigrodigitatus*, which is ultimately hazardous to the health of the fish.

**Figure 3.** Antioxidant enzymes (superoxide dismutase (a), catalase (b) and glutathione-S-transferase (c)) activities in blood samples of *C. nigrodigitatus* from sewage-contaminated fishing waters. All values are expressed as mean ± SEM, n = 6. Asterisks denote significant difference at p < 0.05, ns; no significant difference.

**Figure 4.** Glutathione (a) and Malondialdehyde (b) concentrations in blood samples of *C. nigrodigitatus* from sewage-contaminated fishing waters. All values are expressed as mean ± SEM, n = 6. Asterisks denote significant difference at p < 0.05, ns; no significant difference.
Table 2 shows the proximate composition of *Chrysichthys nigrodigitatus* sampled from Ogun River and Epe Lagoon sites. A significant increase (p < 0.05) was observed in the moisture content of *C. nigrodigitatus* from all the sampled test sites along Ogun River and Epe Lagoon when compared with the controls. The ash content, fat content, crude protein and crude fiber of *C. nigrodigitatus* from all sampled test sites along Ogun River and Epe Lagoon were significantly decreased (p < 0.05) when compared with the respective controls. The moisture content of *C. nigrodigitatus* significantly increased at all the sampled test sites along the Ogun River and Epe Lagoon. This agrees with earlier observation Fafioye *et al.* [12]. Increase in moisture content is indicative of the susceptibility of the fishes to oxidative stress. A high moisture content will allow enzymatic reactions to go on smoothly and thus, is good for living organisms. However, a high moisture content could also be of great disadvantage as it could make fishes more susceptible to spoilage by microbes, increase the oxidative degradation of polyunsaturated fatty acids (PUFAs) and consequently decrease the quality of fishes and reduce their shelf life [41]. The crude protein contents of the *C. nigrodigitatus* obtained from all the sampled sites along Ogun River and Epe Lagoon fell much below 15-28% recommended by FAO [42] (table 2). The protein content of fish is termed as low if it is below 15% [43]. The significant decrease (p < 0.05) observed in the crude protein content of *C. nigrodigitatus* from all sampled test sites along Ogun River and Epe Lagoon may be attributed to the effect of the stressful condition necessitated by exposure to heavy metals [44]. The observed lower crude protein content values of *C. nigrodigitatus* from all sampled test sites compared with the respective controls is indicative of their low protein content. This observed decrease is consistent with that reported by Adebayo *et al.* [45].
Table 2: Proximate composition of *Chrysichthys nigrodigitatus* sampled from Ogun River and Epe Lagoon sites

<table>
<thead>
<tr>
<th>Parameters (%)</th>
<th>Ogun River</th>
<th>Epe Lagoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>Control</td>
<td>Alaapa</td>
</tr>
<tr>
<td></td>
<td>74.25±0.35a</td>
<td>80.31±0.48bc</td>
</tr>
<tr>
<td>Ash content</td>
<td>5.80±0.38b</td>
<td>5.43±0.19b</td>
</tr>
<tr>
<td>Fat content</td>
<td>2.70±0.36b</td>
<td>1.14±0.03a</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>1.75±0.22bc</td>
<td>1.42±0.09ab</td>
</tr>
<tr>
<td>Crude protein</td>
<td>14.65±0.03c</td>
<td>10.65±1.10b</td>
</tr>
<tr>
<td>Nitrogen-free</td>
<td>1.33±0.07a</td>
<td>1.40±0.12a</td>
</tr>
</tbody>
</table>

All values are expressed as mean ± SEM. Values with different superscripts are significantly different (p < 0.05) across the row.

According to Ackman [46], fishes are divided into four categories based on their fat content: lean fishes (< 2 %), low fat fishes (2–4 %), medium fat fishes (4 – 8 %), and high fat fishes (> 8 %). The *C. nigrodigitatus* from the control sites fell within the low-fat category while the *C. nigrodigitatus* from all the test sites fell within the lean category. A significant decrease (p < 0.05) was observed in the crude fat of *C. nigrodigitatus* from all the test sites which indicates a reduction in the nutritive value and the occurrence of fat oxidation which might be attributed to the adaptation of the fishes to the energy requirement of the oxidative stress exerted by heavy metals. The observed decrease in ash content might be due to competition with heavy metals and pollutants. The total carbohydrate component is crude fiber and soluble carbohydrate (NFE). NFE is the source of energy since most fishes cannot digest fiber. The crude fiber content of *C. nigrodigitatus* sampled from Quarry, Oluwo and Marina sites significantly decreased (p < 0.05) compared with the respective controls. The observed decrease in the crude fiber content of *C. nigrodigitatus* sampled from Ogun River and Epe Lagoon might be indicative of a reduced facilitation of regular bowel movement when consumed. In a previous study, Modibbo et al. [47] reported a similar decrease in the crude fiber content of another specie of catfish, *Clarias gariepinus*. No significant difference (p > 0.05) was observed in the NFE of *C. nigrodigitatus* from all the sampled test sites along Ogun River and Epe Lagoon compared with the respective controls.

In summary, the various alterations observed in the activities and concentrations of the studied biomarkers of oxidative stress in the whole blood and plasma of *C. nigrodigitatus* from Ogun River and Epe Lagoon as well as its decreased nutritional value is a resultant effect of exposure to heavy
metals (arsenic, lead and cadmium) present in the fishing waters caused by sewage pollution at each of the sites and hence, serves as an early warning against the deleterious effects sewage pollution of aquatic habitat causes.

CONCLUSION

From the results of the study, it could be concluded that sewage pollution of Ogun River and Epe Lagoon induced oxidative stress and significantly decreased the nutritional value and consequently the economic value of *C. nigrodigitatus* sampled from the fishing waters.

REFERENCES


