Fountain Journal of Basic Medical and Health Sciences (FUJBMHES), 1(2), 26 – 35.

Biochemical Responses of African Catfish (*C. gariepinus*) to the Phytochemical Properties of *S. occidentalis* Leaf

Adesanya, E. O.[1], Idowu, A. A.[1*], Towolawi, A. T.[2], & Adekola M. B.[3]

[1]Department of Aquaculture and Fisheries Management, Federal University of Agriculture, Abeokuta (FUNAAB), PMB 2240, Ogun state, Nigeria;
[2]Department of Environmental Health Science, Fountain University, Osogbo, Osun State, Nigeria;
[3]Department of Environmental Management and Toxicology, Federal University of Agriculture, Abeokuta (FUNAAB), PMB 2240, Ogun State, Nigeria.

Corresponding author: idowudoyin@yahoo.com, +2348133583550, attowolawi@fuo.edu.ng; 4desanyaoluwatosin@gmail.com

Abstract

Background: Consumers of fish food and products have become increasingly concerned with their health and are curious about the safety of the fish they consume. *Senna occidentalis* has proven to be medicinal and toxic. However, the leaves of *S. occidentalis* are among the medicinal and poisonous plants whose toxicity on fish has yet to be studied extensively. **Objective**: This study examined the qualitative and quantitative phytochemical profile of *S. occidentalis* for the biochemical activities of *Clarias gariepinus* exposed to its ethanol leaf extract. **Methodology**: A total of one hundred and twenty (120) juveniles of *C. gariepinus* were acclimatised for two weeks and randomly distributed into 12 plastic tanks of 35-litre capacity. Phytochemical screening and biochemical analysis of the experimental fish were carried out. Analysis of variance (ANOVA) was used to assess the data, and the distinction between the treatment groups was found using the least significant difference (LSD) at a 0.05 statistical level. **Results**: The ethanol leaf extract of *S. occidentalis* phytochemical analysis revealed that the plant's leaf qualitatively contained different bioactive substances such as alkaloids, flavonoids, tannins, saponins, glycosides, and steroids. For the biochemical parameters (Total Protein, Albumin, Globulin, AST (aspartate aminotransferase), ALP (alkaline phosphatase), ALT (alanine transamin*a*se), and GGT (gammaglutamyl transferase) analyses to know the potency of *S. occidentalis* ethanol leaf extract on *C. gariepinus* juveniles, the results indicated that the Total Protein (5.6 – 5.1 g/dl) values decreased with increased concentration of *S. occidentalis* ethanol leaf extract. **Conclusion**: The findings revealed biochemical alterations and damage in the organ of *C. gariepinus*. The higher the *S. occidentalis* ethanol leaf extract concentration, the higher the observed damage. **Recommendations**: The study suggests the usage of another solvent and methods of extraction.

Keywords: Alkaline Phosphate, Albumin, *S. occidentalis,* Fish toxicology, SDG15: life beneath water

Introduction

According to Issa et al. (2022), aquaculture is rapidly growing worldwide and has the sustainable capacity to supply a sizable amount of protein for human consumption. According to Onyekuru et al. (2019), Nigeria's fish demand is 1.4 million metric tons. In contrast, the country's total annual fish supply from capture and cultural fisheries is less than 0.7 million metric tons. As a result, about 0.7 million metric tons of fish, worth $500 million a year, must be imported to close the gap between supply and demand (Issa et al*.,* 2022). Optimum utilisation of aquatic resources and ecosystems at large has been inhibited by pollutants (Umar & Aisami, 2020; Umar & Shukor, 2020), which adversely affect non-target organisms, especially fish, and this may lead to massive mortalities in acute and chronic exposure (Salim, et al*.,* 2021). Aquatic pollution is a major global problem of this century owing to the addition of various pollutants into water bodies through many anthropogenic and natural ways bringing about changes in water qualities (Salim et al*.,* 2021).

Senna occidentalis (L.) Link (Leguminosae), formerly named *Cassia occidentalis (L.)* (Egharevba et al., 2010), is a weed and pollution source that develops across agitated regions, roadside channels, pastures, grasslands, open woodlands, and coastal areas (Vashishtha et al*.,* 2009). Its leaf contains important phytochemicals including tannins, alkaloids, flavonoids, steroids, saponins, anthraquinones, and phlobatannins (Ibrahim et al., 2015). Phytochemicals are vital metabolites that are crucial for the biological processes that occur in plants, such as cell division, growth, and development (Deshmukh & Madhuri, 2018). Flavonoids, alkaloids, saponins, glycosides, terpenoids, tannins, steroids, lignin, anthraquinone, quinones, coumarin, emodins, and betacyanin are a few examples of phytochemicals, as the metabolites found in plants (Bauer et al., 2012). Alkaloids are among the most significant chemical compounds found in herbs. Studies have shown that alkaloids have antimicrobial, anticancer, cytotoxic, and antimalarial properties (Maryam et al*.,* 2012). Flavonoids have antibacterial activity, which makes them very effective in treating viral infections, certain allergies, cancer, inflammations, and certain types of inflammation (Maryam et al*.,* 2012). Tannins change the availability and utilization of amino acids in protein. Additionally, it forms insoluble complexes with proteins and impairs the activity of digestive enzymes, which are known to lower the digestibility of food proteins (Morrow, 1991; Griffiths & Moseley, 1980; Sharma & Sehgal, 1992; Ogunlade et al., 2011). Saponins have antifungal, anti-inflammatory, fungistatic, hemolytic, molluscidal, and foaming properties. They further impact the body's immunological system, reducing cholesterol and preventing cancer (Shi et al*.*, 2004). According to a toxicology study, *S. occidentalis* seeds pose significant toxic effects on animals (Tasaka et al*.,* 2000); cattle and other ruminants have been poisoned by the seeds. The leaf part of this plant is widely consumed in Africa, although little is known about its possible toxic effects on vital organs. More so, people often eat infected fish without realising it, because *C. gariepinus* is a species of fish with a stronger immunity when compared with other fish species. Often, the fish may not show outward signs of infection. On the other hand, eating contaminated seafood can put people at risk for several illnesses (Valerio et al*.,* 2016), indicating that the overall wellness of fish species in aquaculture needs to be assessed using biochemical tests are a consistent and effective method (Mohammed and Sambo, 2008).

Materials and Methods

Geographical Location of Study

The study was carried out at the Fish Hatchery Complex, Department of Aquaculture and Fisheries Management, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

Preparation of Plant Extracts and Extraction of Phytochemicals

The *S. occidentalis* fresh leaves were obtained, air-dried for two weeks, and ground with an electronic blender. Some of the blended/pulverised form was taken for quantitative and qualitative analysis, and used for phytochemical screening. Some powdered leaf of *S. occidentalis* were soaked in 70% ethanol (70% ethanol: 30% water), the solution was stirred continuously at 72-hour interval; this was consistent with Jun et al. (2012), who reported that extraction of phytochemicals can be highly effective when an organic solvent is mixed with an aqueous solvent. The extracted solution was filtered and taken to Lagos University Teaching Hospital (LUTH), where the samples were concentrated with the aid of a rotary evaporator (40 °C), which evaporates the solvent. The remnant was oven-dried to achieve a highly concentrated extract. The extract was further kept in a refrigerator using an air-tight container.

Collection of juveniles of Clarias gariepinus

A total of one hundred and twenty (120) juveniles of *Clarias gariepinus* with an initial average body weight of 16 ± 2 grams and length of 8.5 ± 0.5 cm were obtained from Path Farm, Sagamu, Remo, Ogun State, Nigeria, and transported in a 50-liter keg to the Fish Hatchery, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

Acclimatisation of the Clarias gariepinus Juveniles

The *C. gariepinus* juveniles were acclimatised for two weeks, when they were fed 1.8 mm with an imported commercial feed, which contained 45% crude protein, two times a day, in the early and late hours of the day. Feeding was stopped 48 hours to the beginning of the experiment; wastes were taken out every day while replenishing the water (renewal bioassay technique).

Collection of Senna occidentalis leaves

The leaves of *Senna occidentalis* were obtained at old Bola Ahmed Tinubu (off Iju) Road, Ifako-Ijaiye LGA, Lagos State, Nigeria, and authenticated at the Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta.

Experimental Design and Procedure

The experiment had four treatments with three replicates each containing ten fish per treatment tank. One hundred and twenty (120) juvenile catfish were randomly distributed in twelve plastic tanks of 35 liters capacity but filled with 15 liters of water for the experiment. One control and three sub-acute concentrations of 3000 mg/ 25 cL, 5000 mg/ 25 cL, and 7000 mg/ 25 cL were prepared and triplicated for each treatment in a transparent plastic container. A 5 mL of each concentration was daily infused into the plastic tanks for 21 days of the renewal-bioassay experiment.

Phytochemical Screening

A phytochemical screening process was applied to the extract of *S. occidentalis* leaves to determine the qualitative and quantitative chemical constituents. The screening was done at the Biology Laboratory, Redeemers University, Ede, Osun State, Nigeria.

Determination of Biochemical Parameters

Gamma Glutamyltransferase (GGT)

The GGT was determined spectrophotometrically using the XpressBio Diagnostic kit.

Reagent preparation

Precisely 27 mL of deionised or distilled water was added to the powdered GGT Reagent Mix to reconstitute it. Mix by giving the bottle ten turns or swirls. At room temperature, the contents were given ten minutes to dissolve. The complete kit was kept at -20 °C in between uses after the GGT Reagent Mix was reconstituted. But before every use, the frozen liquid component was quickly thawed and brought to room temperature. Before use, the reconstituted GGT Reagent Mix was briefly kept at room temperature (30 to 60 minutes). For a maximum of six months, the reconstituted GGT Reagent Mix was kept at -20 °C. After reconstitution, the GGT Reagent Mix should be thrown away after six months. A temperature-controlled plate reader was set to 37 °C, and the GGT Reagent Mix was allowed to acclimate to that temperature for ten minutes before use to obtain higher sensitivity measurements.

Procedure:

Allow assay components to warm to room temperature before use. Fill each microplate well with 10 uL of the standard or sample (in replicate). To the wells, add 240 uL of the GGT Reagent Mix. Take a quick reading of each sample's absorbance at 405 nm. Measure the absorbance once more precisely after ten minutes. Subtract the initial time from 10-minute time point's absorbance to find the increase in absorbance at 10-minute interval for each point. A conventional calibration curve was used to calculate the GGT enzymatic activity.

Determination of Aspartate Aminotransferase (AST)

Reagent 1 (R1) contains 100 mmol/ L phosphate buffer at pH 7.4, 100 mmol/ L of L-aspartate, and 2 mmol/ L of α-oxoglutarate. Reagent 2 (R2) contains 2 mmol/ L of 2,4-dinitrophenylhydrazine.

Procedure:

A test tube rack held two sterile test tubes with the labels Test (T) and Blank (B). Each test tube received 0.1 mL of serum and distilled water, respectively. Following the addition of 0.5 mL of R1 to each test tube, the mixture was mixed and allowed to sit at 37 °C for 30 minutes. Following the addition of 0.5 mL of R2, the mixtures were once more incubated for 20 minutes at room temperature. Five minutes later, 5 mL of sodium hydroxide was added, and the absorbances were measured at 546 nm. The table was used to determine the AST activity provided in the Randox kit to construct a linear graph of absorbance against concentration. AST activities of the samples were extrapolated from the standard graph.

Determination of Alanine Transaminase (ALT)

Reagent 1 (R1) contains 100 mmol/ L phosphate buffer at pH 7.4, 200 mmol/ L of L-alanine, and 2 mmol/ L of α-oxoglutarate. Reagent 2 (R2) contains 2 mmol/ L of 2, 4-dinitrophenylhydrazine.

Procedure:

Two clean test tubes labeled blank (B) and Test (T) were arranged in a test tube rack. A 0.1 mL of distilled water and serum were added to each of the test tubes, respectively. A 0.5 mL of R1 was then added to all the test tubes, mixed, and incubated for 30 min at 37 ºC. A 0.5 mL of R2 was then added, and the mixtures were again incubated for 20 min at room temperature, after which 5 mL of sodium hydroxide was added, and the absorbances were read at 546 nm after 5 min. The activity of ALT was obtained using the table provided in the Randox kit to construct a linear graph of absorbance against concentration. The ALT activities of the samples were extrapolated from the standard graph.

Determination of Total Protein

Using a Randox kit, the protein concentration was measured spectrophotometrically. Reagent 2 contains the blank reagent (R2), which is composed of Sodium hydroxide (100 mmol/ L), Sodium Potassium tartrate (16 mmol/ L), Potassium iodide (15 mmol/ L), and Cupric Sulphate (6 mmol/ L). Reagent 1 (R1) contains the Biuret reagent.

Procedure:

A test tube rack held three sterile test tubes with the labels blank (B), standard (S), and test (T). In that order, each test tube received 0.02 ml of distilled water, standard protein, and serum. After adding 1 mL of R1 to each test tube, the mixture was stirred and allowed to sit at room temperature for 30 minutes. At a wavelength of 546 nm, the absorbance of the standard and the samples was measured.

Protein Conc. (mg/dl) = (Absorbance of test/Absorbance of standard) X Conc. of Std

Determination of Albumin Concentration

Albumin concentration was determined spectrophotometrically by the Randox kit. Reagent 1 (R1) contains BCG concentrate which comprises succinate buffer (75 mmol/L; pH 4.2), Bromocresol green 0.15 mmol/L, Brij 35, and preservative

Procedure:

A test tube rack held three sterile test tubes with the labels blank (B), standard (S), and test (T). 87 millilitres of distilled water were used to dilute one bottle of R1. Each test tube received 0.01 ml of distilled water, standard protein, and serum in that order. After adding 3 ml of the diluted reagent to each test tube, the mixture was mixed and allowed to sit at room temperature for five minutes. At 630 nm, the absorbance of the standard and the samples was measured.

Albumin Conc. (mg/dl) = (Absorbance of test/Absorbance of standard) X Conc. of Std

Statistical Analysis

The data were assessed using analysis of variance (ANOVA), and the distinction between treatment groups was found using the least significant difference (LSD) at the 0.05 significance level. The toxicity indices were obtained using SPSS (version 20.0).

Result

The ethanol leaf extract of *S. occidentalis* underwent phytochemical analysis, revealing that the plant's leaves contained different amounts of several bioactive substances, such as alkaloids, flavonoids, tannins, saponins, glycosides, and steroids (Table 1). Phytochemical analysis showed that alkaloids and saponins were strongly present in the ethanol leaf extract of *S. occidentalis*. However, flavonoids, tannins, glycosides, and steroids showed a weak presence in the ethanol leaf extract of *S. occidentalis*. According to Nelson and Cox (2000), it is critical to examine the harmful consequences of contaminants using pertinent diagnostic methods like AST, ALP, and ALT. The Analysis of variance (ANOVA) showed that there is a significant difference ($p < 0.05$) among the parameters (Table 2).

Discussion

The contamination of freshwater by different pollutants, such as decayed plant phytochemicals, has brought about significant problems to aquatic organisms (Muhammad et al., 2021). Various solvents (such as aqueous, methanol, and ethanol) influence the difference in phytochemical extract concentration, accounting for differences in the plant extract toxicities, even for the same dose. The *S. occidentalis* leaf revealed a high presence of alkaloid, (27.60 ± 0.2) as seen in Table 1, which could cause detoxification failure and damage to the liver agreeing with Innocent et al. (2022), who worked on the phytochemical constituents of *S occidentalis* and saponin (22.17 ± 0.02), which possesses some adverse effects due to its cytotoxic nature. Although saponin has the potential to act as a chemotherapeutic agent, its high presence in the plant results in hemolysis, aligning with the study of Sparg et al. (2004), where saponins caused hemolysis; this may hinder its contribution to the making of anti-cancerous drugs (Sheikh *et al.*, 2021). Ferrari et al. (2007) stated that blood biochemical component provides valuable insights into identifying and diagnosing fish illnesses and metabolic abnormalities. Studies indicated that the most important and valuable enzymes in animal blood tests are AST, ALT, GGT, etc. (Schaller et al., 2008; Zaitsev, 2010; Zaitsev, 2016).

Table 1: Quantitative constituents of phytochemicals in ethanol leaf extract of *S. occidentalis*

Phytochemicals	Sample A	Sample B	Sample C
Saponin	22.17^{a}	22.15^{a}	22.20_{ab}
Alkaloids	27.80^{a}	27.50^{a}	27.50^{a}
Flavonoids	12.92^{b}	12.88^{a}	12.88^{a}
Tannins	14.50^{a}	14.50^{a}	14.40^{a}
Glycosides	11.50^{a}	11.40^{a}	11.40^{a}
Steroids	11.60^{b}	11.20^{a}	11.20^{a}

Table 2: Shows the results of serum biochemistry of *S. occidentalis* on *C. gariepinus*

Parameters	Control	Treatment A	Treatment B	Treatment C
Conc./ 25 cL	0 mg	3000 mg	5000 mg	7000 mg
Total Protein (g/dl)	5.4[c]	5.3[d]	5.4[c]	5.1[a]
Albumin (g/dl)	3.7 cd	3.6[d]	3.5[c]	2.8[a]
Glob (g/dl)	1.7[a]	1.7[a]	1.9[a]	2.3[b]
AST (U/L)	232[b]	268[c]	229[b]	157[a]
ALP (U/L)	117[d]	93 c	75[b]	63 a
ALT (U/L)	91[d]	81 c	69[a]	71 b
GGT (U/L)	14.9[b]	14.3[b]	11.8[a]	11.5[a]

Means in each row with different superscripts are significantly different at p<0.05
Glob = globulin, AST = aspartate aminotransferase, ALP = alkaline phosphatase, ALT = alanine transaminase, and GGT = gamma-glutamyl transferase.

This study examined the hepatic enzymes transaminases and alkaline phosphatase, which are significantly helpful in tracking the fish's health (Racicot et al., 1975).

The serum's total protein and albumin values dropped, probably due to a rise in *S. occidentalis* concentrations, and pointed to the toxic impacts of the test plant on the liver function of *C. gariepinus* juveniles; this agreed with observation of Hakk *et al*. (2002) mentioning that "the decrease in albumin and globulin levels in the blood of fish exposed to CBL may be caused by the destruction of their biological structure after binding to the xenobiotics in the cigarette but leachate." It can be said that the detoxification failure caused by the high presence of *S. occidentalis* leaf Alkaloids significantly reduces albumin and total protein, which sustains the osmotic pressure of the blood and immune response according to Hakk *et al*. (2002); this could influence the C. gariepinus juveniles' health and survival.

There was also a notable decrease in the *C. gariepinus* blood's ALP, ALT, AST, and GGT, from the *S. occidentalis* ethanol leaf extract, agreeing with the study of Muthukumaravel et al. (2023), for an adverse effect on the test fish hepatic cells; this also agrees with Zeidi et al. (2023), who mentioned that "the decreased ALP activity may indicate dysfunction or damage to the liver and intestinal epithelium in aquatic animals exposed to xenobiotics", atrophy of hepatocytes, respectively. This could lead to a reduction in liver functionality as sinusoidal congestion means a blockage of channels through which blood flows in the liver, resulting in cirrhosis, agreeing with Jia et al. (2022), who observed that a shrinkage of the hepatic cells could result in cirrhosis and impediment of portal flow through the liver.

Conclusion

Fishes are very sensitive aquatic organisms that respond to changes in their environment, whether physical, chemical, or biological. Although, the *S. occidentalis* phytochemicals are medicinal, their toxicity when present in high amounts on target organs such as the liver, kidney, and the blood of fishes necessitated control of the water pollution for finding its way into the aquatic environment, irrespective of the source of pollution (Salim et al*.,* 2021). The aquatic organisms, such as fish, are sensitive to environmental changes. The *S. occidentalis* toxicity on *C. gariepinus* juveniles was pronounced in the highest concentrations and the last exposure period.

Recommendations

The study recommends using *S. occidentalis* with a treatment level not exceeding 2000 mg/ 25 cL of water for C. gariepinus juveniles. It also suggests using other organic solvents to extract the plant phytochemicals and comparing the results with the outcomes of this research for the biochemical changes in aquatic organisms.

Toxicological implications of the study

- ❖ Knowledge of plant toxicity: Safety in the consumption of agricultural resources can only be guaranteed when adequate knowledge of plant toxicity and its implications exists. Farmers should expand their frontier of knowledge on the toxicity of plants such as *S. occidentalis*, which possesses a dual property: it is medicinal and toxic when used in large quantities.
- ❖ Research and review: Research work and review of research works provide necessary information that can guide farmers when using toxic plants.
- ❖ Environmental Impact: The presence of phytochemicals varies according to location. Therefore, farmers may need to conduct phytochemical analyses of *S. occidentalis* to make the right decisions about on-farm activities.
- ❖ Seasonal Variation: Seasonal variations affect the toxicity of S. occidentalis. Climate change impacts plant chemical constituents. This should be considered.

Limitations of the study

❖ Insufficient information and knowledge: This study only focused on the leaves of *S. occidentalis*; therefore, research should be done on other parts of the plants.

❖Seasonal impact and availability: It was observed that the plant blossoms during the rainy season; during the dry season, it is not easy to harvest many leaves for study.

Ethical consideration

The author did not conduct an experimental trial that required a human sample. Therefore, there was no need for ethical approval.

Conflict of interest

The author declares no conflict of interest.

Acknowledgements

The authors appreciate one another for their cooperation and contributions to achieving a successful goal. We also appreciate the reviewers of this article for their contributions, which give more meaning to this study.

References

Bauer, C. M., Johnson, E. K., & Beebe-Dimmer, J. L. (2012). Prevalence and correlates of vitamin and supplement usage among men with a family history of prostate cancer. *Journal of Integrative Cancer Therapies*, 11(2), 83-89.

Deshmukh, M. I., & Madhuri, A. T. (2018). Phytochemical screening, qualitative analysis of primary and secondary metabolites of *Acacia arabica* Bark. *International Journal of Current Pharmaceutical Research,* 10(2), 35.

Egharevba, H. O., Odigwe, A. C., Abdullahi, M. S., Okwute, S. K., & Okogun, J. I. (2010). Phytochemical analysis and broad-spectrum antimicrobial activity of *Cassia occidentalis* (L.) (whole plant). *New York Science J.,* 3(10), 74 – 81.

Ferrari, A., Venturino, A., Pechén, A. M., and D'Angelo 2007. Effects of carbaryl and azinphos methyl on juvenile rainbow trout (*Oncorhynchus mykiss*) detoxifying enzymes. *Pesticide Biochemistry and Physiology,* 88(2),134-142.

Griffiths, D. W., & Moseley, G. (1980). The effect of diets containing field beans of high or low polyphenolic content on the activity of digestive enzymes in the intestines of rats. *Journal of the Science of Food and Agriculture,* 31(3), 255–259. doi:10.1002/

Hakk, H., Larsen, G., Bergman, Å., & Örn, U. (2002). Binding of brominated diphenyl ethers to male rat carrier proteins. *Xenobiotica*, 32(12), 1079-1091, 10.1080/0049825021000016345

Ibrahim, A. M., Lawal, B., Tsado, N. A., Yusuf, A. A., & Jimoh, A. M. (2015). Phytochemical screening and GC-MS determination of bioactive constituents from methanol leaf extract of *Senna occidentalis*. *Journal of Coastal Life Medicine,* 3(12), 992-995.

Innocent, I. U., Chukwuebuka, K. O., & Onyekachi, E. O. (2022). Phytochemical and vitamin constituents of *Senna occidentalis* (Linn). *GSC Advanced Research and Reviews*, 11(1), 011–020.

Issa, F. O., Aderinoye-AbdulWahab, S., Kagbu, J. H., & Adisa, R. A. 2022. Assessment of Aquaculture Development Programmes in Nigeria*. Journal of Agricultural Extension*, 26(1), 18.

Jia, R., Hou, Y., Feng, W., Li, B., & Zhu, J. (2022). Alterations at biochemical, proteomic, and transcriptomic levels in the liver of tilapia (*Oreochromis niloticus*) under chronic exposure to environmentally relevant levels of glyphosate. *Chemosphere*, 294, 133818.

Jun, H., Song, G., Yang, E., Youn, Y., & Kim, Y. (2012). Antioxidant activities and phenolic compounds of pigmented rice bran extracts. *Journal of Food Science*, 77(7), C759–C764.

Muthukumaravel, K., Priyadharshini, M., Kanagavalli, V., Vasanthi, N., Ahmed, M. S., Musthafa, M. S., Shukla, S., Khan, R., Rajagopal, R., Chang, S. W., & Ravindran. B. (2023). Impact of sublethal phenol in freshwater fish *Labeo rohita* on biochemical and hematological parameters. *Environ. Monit.* Assess., 195(1), 10, DOI.10.1007/s10661-022-10554-2

Maryam J., Bushra, M., Abida, Y., & Mir, A. K. (2012). Pharmacological activities of selected plant species and their phytochemical analysis. *Journal of Medicinal Plant Research*, 6, 50135022.

Mohammed, A. K., & Sambo, A. B. (2008). Hematological assessment of the Nile tilapia (*Oreochromis niloticus*) exposed to sublethal concentrations of Portland cement powder in solution. *International Journal of Zoological Research,* 4(1), 48–52.

Morrow, B. (1991). The rebirth of legumes. *Food Technology,* 45(9), 96–121.

Muhammad, U. A., Yasid, N. A., Daud, H. M., & Shukor, M. Y. (2021). Glyphosate herbicide induces changes in the growth pattern and somatic indices of crossbred red Tilapia (*O. niloticus*; *O. mossambicus*). *Animals,* 11(5), 1209. DOI:10.3390/ani11051209

Nelson, D. L., & Cox, M. M. (2000). Lehninger principles of biochemistry. *New York: Worth Publishers*. Pp. 623-658.

Ogunlade, I., Ilugbiyin, A., & Osasona, A. I. (2011). A comparative study of proximate composition, anti-nutrient composition, and functional properties of *Pachira glabra* and *Afzelia africana* seed flours. *African Journal of Food Science*, 5(1), 32–35.

Onyekuru, N. A., Ihemezie, E. J., & Chima, C. C. (2019). Socio-economic and profitability analysis of catfish production: A case study of Nsukka Local Government Area of Enugu State, Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension,* 18(2), 51-58.

Racicot, J. G., Gaudet, M., & Leray, C. (1975). Blood and liver enzymes in rainbow trout (*Salmo gaidneri* Rich.) with emphasis on their diagnostic use: Study of CC14 toxicity and a case of Aeromonas infection. *Journal of Fish Biology,* 7, 825-835.

Salim, A. M., Yusuf, M. A., & Bichi, A. H. (2021). Haematological responses of African Catfish (*Clarias Gariepinus*, Burchell, 1822) juveniles exposed to acute concentrations of Butachlor (Herbicide). *FUDMA Journal of Agriculture and Agricultural Technology*, 7(2), 110-115.

Schaller, J., Gerber, S., Kaempfer, U., Lejon, S., & Trachsel, C. (2008). Human blood plasma proteins: structure and function. *New York*: Wiley.

Sharma, A., & Sehgal, S. (1992). Effect of domestic processing, cooking, and germination on the trypsin-inhibitor activity and tannin content of faba bean (*Vicia faba*). *Plant Foods for Human Nutrition,* 42(2), 127–133. DOI:10.1007/BF02196465.

Sheikh, A., Kim, K., Varaprasad, G. L., Lee, H., Kim, S. E. (2021). The anti-cancerous activity of the adaptogenic herb *Astragalus membranaceus,* Phytomedicine: *International Journal of Phytotherapy and Phytopharmacology*, 91(2021), Article 153698.

Shi, J., Arunasalam, K., Yeung, D., Kakuda, Y., Mittal, G., & Jiang, Y. M. (2004). Saponins from edible legumes: chemistry, processing, and health benefits. *Journal of Medicinal Food*, 7(1), 67– 78. doi:10.1089/ 109662004322984734

Sparg, S. G., Light, M. E., & Van-staden, J. (2004). Biological activities and distribution of plant saponins. *J Ethnopharmacol.,* 94, 219-243.

Tasaka, A. C., Weg, R., Calore, E. E., Sinhorini, I. L., Dagli, M. L., Haraguchi, M., & Górniak, S. L. (2000). Toxicity testing of *Senna occidentalis* seed in rabbits. *Vet Res Commun*, 24(8), 573-582.

Umar, A. M., & Aisami, A. (2020). Acetylcholinesterase enzyme (AChE) as a biosensor and biomarker for pesticides: A mini-review. *Bulletin of Environmental Sci. and Sustain. Manag.,* 4, 7– 12.

Umar, A.M., & Shukor, M. Y. A. (2020). Modelling the growth of Nile tilapia (*Oreochromis niloticus*) on fed diets formulated from local ingredients in cages. *Bulletin of Environmental Sci. and Sustain. Manag.,* 4, 1-6.

Valerio, F., Biase, M., Lattanzio, V. M., & Lavermicocca, P. (2016). Improvement of antifungal activity of lactic acid and bacteria by addition to the growth medium of phenylpyruvic acid, a precursor of phenyl lactic acid. *Int. J. Food Microbiol.,* 222, 1-7. Doi: 10.1016. PMID: 26827290.

Vashishtha, V. M., John, T. J., & Kumar, A. (2009). Clinical and Pathological features of acute toxicity due to *Cassia occidentalis* in vertebrates. *Indian Journal of Medical Research,* 130(1), 23-30.

Zaitsev S. Y. (2010). Supramolecular nanosized systems at the phase interface: concepts and prospects for bio-nanotechnologies. Moscow: LENAND.

Zaitsev, S. Y. (2016). Tensiometric and biochemical analysis of animal blood: fundamental and applied aspects. *Moscow*: Publishing House Agricultural Technologies.

Zeidi, A., Sayadi, M. H., Rezaei, M. R., Banaee, M., Gholamhosseini, A., Pastorino, P., Multisati, C.R., & Faggio. C. (2023). Single and combined effects of $CuSO_4$ and polyethene microplastics on biochemical endpoints and physiological impacts on the narrow-clawed crayfish *Pontastacus leptodactylus Chemosphere*, 345(2023), Article 140478, 10.1016/j.chemosphere.2023.140478.

Citation:

Adesanya, E. O., Idowu, A. A., Towolawi, A. T., & Adekola M. B. (2025). Biochemical Responses of African Catfish (*C. gariepinus*) to the Phytochemical Properties of *S. occidentalis* Leaf. *Fountain Journal of Basic Medical and Health Sciences (FUJBMHES), 1(2),* 26 -35.