Nutritional composition of aquatic plants and their potential for use as animal feed: A case study of the Lower Volta Basin, Ghana

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Abstract. Etse WJ, Annang T, Ayivor JS. 2018. Nutritional composition of aquatic plants and their potential for use as animal feed: a case study of the Lower Volta Basin, Ghana. Biofarmasi J Nat Prod Biochem 9: 99-112. The study was conducted to determine the nutritional composition of selected dominant aquatic plants and their significant effect on the chemical and physical characteristics of the water. Aquatic plants namely Nymphaea lotus, Typha australis, Ipomoea aquatica, and Scirpus cubensis were collected, identified and authenticated at the Ghana Herbarium. The proximate nutritional compositions of these plants were measured using the standard procedure outlined in the Association of Official Analytical Chemist (AOAC 2002). Water and sediment quality analyses of some physicochemical variables were also carried out using processes described in the standard methods for water and wastewater examination. The results showed that nutrient composition such as the crude protein, ether extracts, ash content, and nitrogen-free extracts was significantly higher than the corresponding constituents in Panicum maximum used as a control for the study. The findings also indicated that levels of heavy metals in all plants fell within the WHO/FAO standards for metals in vegetables and food. The effects of the physicochemical parameter of water also revealed that pH, nitrate, turbidity, DO, and BOD levels were found significantly different from the control site. The level of heavy metal in the sediment samples revealed significant variations in the distribution of the metals, with Zn showing the most significant difference and Pb the least with a mean level of 7.5±0.86 mg/L and 0.4±0.03 mg/L respectively. These plant species suggests having a high nutritive potential and indicates their possible use as mixed ingredients in animal feed. Exploitation of these aquatic plants for animal feed would be a step towards better utilization of these plants help in the management of aquatic plants within the basin.

Keywords: Aquatic plant, lower volta basin, nutritional composition

INTRODUCTION

Aquatic plants have been conventionally perceived as a nuisance rather than a useful resource for years (Shah et al. 2010) because of the challenges they pose in the environment. The aquatic vegetation can change physicochemical characteristics of both water and hydrosol thereby altering the quality of water (Petosa et al. 2010). They can also provide habitat and food for the larval stage of animal vectors of human diseases such as malaria, therefore posing as a health hazard (El-Shinnawy et al. 2000). Besides the specific effects and the detrimental effect of the excessive growth of aquatic plants described above, aquatic plants may influence the programs of water resource utilization and management (Malik 2007).

In Ghana, several major river systems like the Tano, Pra, Ankobra, Kakum, Ochi, Ayensu and Densu have been affected with severe aquatic macrophyte infestation that has resulted in the improper utilization and management of the impoundments (deGraft-Johnson 1996). Annang (2008) stated that the regulation of the flow regime of the Volta River due to the generation of Akosombo dam in 1963 and Kpong dam in 1981 had created an ideal situation for the quick growth of aquatic plants in the Lower Volta Basin of Ghana (LVB). Thereby, he noted that this has resulted in some of the problems mentioned above. Meanwhile, varieties of water plants including Nymphaea lotus, Ipomoea aquatica, Scirpus cubensis, Typha australis, Ceratophyllum demersum species are abundant in the Volta basin. Aquatic vegetation in the lower Volta has contributed to the level of poverty in the basin communities specifically since it has limited the mobility of fishing boats in the waterways along the basin communities (Annang 2008). Consequently, the Volta River Authority (VRA) purchased four mechanical weed harvesters at a total value of US$ 830,000 (Ghana Bulletin 2013) which are positioned at Kpong for the physical and mechanical harvesting of the aquatic plants at huge expense and dumped the harvested plants as waste without considering utilizing these plants. The cost-benefit of this initiative is however subject to much controversy because elsewhere in another part of the world, water plants are used as biofuels, compost, medicine, animal feed and even as a source of food for humans.

Despite all these adverse effects of aquatic plants, many researchers have documented the chance of using these aquatic plants as a source of animal feed (Anon 1984). The previous study surveyed aquatic plants in Sringar and found out that animals fed with the studied aquatic plants generated approximately 3 liters of milk per day per animal more than animals fed with straw (Shah et al. 2010). These researchs ultimately explore all the possible ways to use these plants as an ingredient in animal feeds to continuously harvest and use the nuisance plants which will subsequently decrease the adverse effects caused by water plants in the aquatic ecosystem.
Therefore, this study suggests that the potential use of water plants as animal feed may provide an efficient, effective, and environmentally friendly means of controlling and managing water plants within the Lower Volta Basin. Specific objectives of this study are to assess the nutrient composition of some dominant aquatic plants using proximate analyses, to identify the phytochemicals exist in the selected samples, to measure heavy metal levels in the water, plant material, and sediment, and to investigate the social perception on the use of aquatic plants in feeding animals.

MATERIALS AND METHODS

Study area
The study was performed on the Lower Volta Basin (LVB) in Ghana, and three sampling sites were chosen (Kpong, Big Ada, and Amedeka). Ada and Kpong area are the stretches on the Lower Volta that is heavily populated with diverse water plants. Water samples were brought from Amedeka where there are no weeds and served as a control site.

Brief description of the sampling sites
Kpong head pond
The surface area is about 37.4 km², with a maximum depth of 15m and an average depth of 5m (Ansa-Asare and Asante 1998). The Kpong head pond has about 85% of its total surface infested with aquatic weeds. Among the numerous plant species present are N. lotus, T. australis, S. cubensis, I. aquatica and Vossia. Human activity mainly through fishing at the site is high.

Big Ada
The Ada sampling site has vegetation typical of savanna transition zone. Species present are T. australis, I. aquatica, S. cubensis, and some terrestrial plant species. Fishing is a significant activity in the area. Furthermore, recreational activities such as swimming and boating are common practices within the region.

Short description of plants under study

**Typha australis** Schumach.
*Typha australis* belongs to family Typhaceae, common names as cattail, punks, reedmace, bulrush, corn dog grass, etc. The rhizomes are edible.

*Typha* is often found to colonize areas of newly exposed wet mud, with its abundant wind-dispersed seeds. Seeds can survive inside the soil for long periods of time. The seeds germinate best with sunlight and fluctuating temperatures, which is typical of many wetland plants that regenerate on mud flats. Rhizomes also spread Thypa, forming large, interconnected stands. It is considered to be the dominant competitors in wetlands in many regions, and it often eliminates other plant species with its large canopy. In the Great Lakes bay, for instance, it is among the most abundant wetland plants. Different species of cattails adapted to different water depths. *Typha* can be aggressive in their competition with other indigenous species and has become a problem in many regions in North America. It may be more critical to avoid invasion by preserving water level fluctuations, including periods of drought, and to keep infertile conditions (Gott 1999).

**Nymphaea lotus** Linn.
*Nymphaea lotus* belongs to the family Nymphaeaceae, a species of water lily with lily pads which float on the water, and the flower blossoms above the water. The color of the flower is white and sometimes tinged with pink. It is found in ponds and prefers clear, warm, still and slightly acidic waters. The plant can be located in association with other water plant species such as *Utricularia stellaris*. The plant is invasive of any stretch of calm water. It has colonized parts of the Volta Lake (Wiersema 1982).

Figure 1. Map of the study area in Lower Volta Basin, Ghana
Ipomoea aquatica Forsk.

*Ipomoea aquatica* belongs to the family Convolvulaceae. It is a semiaquatic, tropical plant grown as a vegetable for its tender shoots and leaves. This plant is called as water spinach in English and increases in water or moist soil. They are hollow and can float. Propagation is either by the planting seeds from flowers or planting cuttings of the stem shoots that will root along nodes (Prasad et al. 2008).

Scirpus cubensis Poeppig & Kunth

*Scirpus cubensis* is a leafy plant which belongs to the family Cyperaceae. The large colony of medium-height grasses grows in water, with spherical inflorescences only somewhat visible among the many leaves. It is a significant duck food (Junk and Piedade 1997).

General methods

The study adopted quantitative and qualitative approaches of data collection. Plant, water and sediment samples were analyzed quantitatively in the laboratory using appropriate protocols. Four different plant species namely *N. lotus*, *T. australis*, *I. aquatica*, and *S. cubensis* were taken from each of the sampling sites from January to March. Water and sediment were also taken from the same sample locations for analysis.

Reconnaissance survey

A reconnaissance survey was performed on the 13th and 14th of January, 2015 to assess the problems in the various regions. Two sampling sites were chosen using a judgment sampling technique after the survey to identify significant environmental challenges. Garman Etrex 20 Global Positioning System (GPS) recorded the coordinates of the sampling sites.

Aquatic plants

Plant samples collection

Four different plant species were collected from Ada and Kpong and transferred into black polyethylene bags from the sampling sites to the laboratory. The plants were selected based on dominance, availability, and accessibility at the two sampling sites to allow for comparison between the plant taken at the two sampling locations.

Plant sample identification

The herbarium of the Botany Department, University of Ghana, Legon identified and authenticated *T. australis*, *N. lotus*, *I. aquatica* and *S. cubensis*.

Plant sample preparation

Plant samples were rinsed with water and then dried for one week in an oven at a temperature of 50°C. The dried samples were pulverized and kept for further analysis.

Plant samples analysis

Proximate determination

Moisture content was measured by the loss in weight that occurs when the sample was dried to a constant weight in an oven. Two grams of the plant sample was weighed, and the sample was then dried in an oven for 36 hours, at 65 0C cool in a desiccator and weighed. The process was continued until a stable weight was achieved.

\[
\% \text{Moisture} = \frac{(\text{wt of sample + dish before drying}) - (\text{wt of sample + dish after drying})}{\text{wt of sample taken}} \times 100
\]

Ether extract

The ether extraction by soxhlet apparatus represents the fat and oil in the plant sample. This equipment consists of 3 main components; an extractor which comprises the thimble which holds the sample; a condenser for cooling and condensing the ether vapor; and a 250 mL flask.

Procedure: 150 mL of anhydrous diethyl ether (petroleum ether) was placed in the flask. Three grams of the sample was weighed into a thimble which was plugged with cotton wool. The thimble with its content was put into the extractor; the ether in the flask was then heated. As the ether vapor arm of the extractor, it condensed to liquid from the sample in the thimble, the ether-soluble substances were dissolved and were carried into the solution through the siphon tube back into the flask. The extraction was performed for 5 hrs. The thimble was removed, and almost all of the solvent was distilled from the flask into the extractor. The flask was disconnected and placed in an oven at 65°C for 4 hours, cooled in the desiccator and weighed.

\[
\% \text{Ether extract} = \frac{\text{wt of flask + extract} - \text{tare wt of flask}}{\text{wt of sample}} \times 100
\]

Crude fibre

Crude fiber determined by the organic residue left after sequential extraction of a sample with ether. The fat-free material was moved to a flask/breaker, and 200 mL of pre-heated 1.25% sulphuric acid was added, and the solution was gently boiled for about 30 mins, maintaining a constant volume of acid by the pouring hot water. The Buckner flask funnel fitted with pre-heated Whatman filter paper. The boiled acid sample mixture was filtered through the funnel under sufficient suction, then washed several times with boiled water (until the residue is neutral to litmus paper) and transferred back into the beaker. Following this step, a 200 mL of pre-heated 1.25% sodium sulfate (Na₂SO₄) was added and boiled for 30 mins, filtered under suction and washed thoroughly with hot water and ethanol twice. The residue was dried at 65 0C for 24 hrs and measured. The residue was moved into a crucible and placed in a muffle furnace (400-600 0C) and ash for 4hrs, then cooled in a desiccator and weighed.

\[
\% \text{Crude fibre} = \frac{\text{Dry wt of residue before ashing - wt of residue after ashing}}{\text{wt of sample}} \times 100
\]

Crude protein

Crude protein was calculated by a Kjeldahl method that involves digestion, distillation, and titration. The nitrogen content of the plant sample was measured and multiplied it by a factor of 6.25 (this factor was based on the fact that most protein contains 16% of nitrogen).
Digestion: 2g of the sample was weighed into Kjeldahl flask and 25 mL of concentrated sulphuric acid, 0.5 g of copper sulfate, 5 g of sodium sulfate and a speck of selenium tablet were added. The heat was applied in a fume cupboard slowly at first to prevent excessive frothing, followed by digestion for 45 mins until the digester became clear pale green. One-hundred mL of distilled water was rapidly added to the samples after cooled down.

Distillation: Markham distillation apparatus was stemmed up, and 10 mL of the digest was added to the device via a funnel and allowed it to boil. Ten mL of sodium hydroxide was added from a measuring cylinder so that ammonia is not lost. It was then distilled into 50 mL of 2% boric acid containing screened methyl red indicator.

Titrination: the alkaline ammonium borate created was titrated directly with 0.1N of 2% boric acid containing screened methyl red indicator. Tests for phenols (Ferric chloride test)

A fraction of the extracts were treated with 5% aqueous ferric chloride and observed for formation of deep blue or black color.

Test for saponins (Foam test)

Six mL of water was added to 2 mL of the extract, shaken vigorously, and observed for the visible foam that confirms the existence of saponins.

Test for amino acids and proteins (1% ninhydrin solution in acetone)

Two mL of filtrate was treated with 2-5 drops of ninhydrin solution placed in a boiling water bath for 1-2 minutes and observed for the formation of a purple color.

Test for terpenoids (Salkowki’s test)

One mL of chloroform was added to 2 mL of each extract followed by three drops of concentrated sulphuric acid. A precipitate was showing a reddish brown color that produced immediately indicated the presence of terpenoids.

Test for sterols (Liebermann-Burchard test)

One mL of the of chloroform, acetic anhydride, and concentrated H2SO4 each was dropped and observed for the formation of dark pink or red color.

Mineral analysis

One gram of the powdered sample was added with 25 mL concentrated HNO3 in a flask. The flask was then heated until the evolution of brown fume stopped. The mixture was added with 1 cm3 of perchloric acid and then heated to a clear solution. After that, 30 mL of hot distilled water was poured to the digest and heated to boiling. The solution was filtered hot into a clean 50 mL volumetric flask, cooled and meshed up to the mark with distilled water. Na and K content was analyzed by flame atomic emission spectrophotometer. Spectrophotometer with standard air-acetylene flame analyzed the content of Ca, Cu, Zn and As.

Water

Water sample collection

A 500 mL plastic bottle was used to fetch water at each sampling point. The samples were kept on ice in the chest to keep the temperature low to suppress microbial activity before transporting it to the laboratory. Nitric acid (3 drops) was added to the water sampled for heavy metal analysis.
Physicochemical analysis of water samples

Water at each sampling point was sampled in a 500 mL plastic bottle. This was later used in the laboratory for further investigation. The samples were kept on ice in the chest to keep the temperature low (about 10 °C) to avoid microbial activity before transporting it to the laboratory. Physicochemical parameters of the water samples were measured at the Ecological laboratory, University of Ghana.

pH

The pH of water samples was determined in situ using a portable pH meter.

Temperature

The temperature was measured in situ to a depth of about four inches for nearly a minute. The readings were allowed to stabilize and noted.

Turbidity

Turbidity was measured using HACH 2100Q. The turbidity meter was powered on after 20NTU (Nephelometric Turbidity Unit) cell was filled with the sample, cleaned, and placed in the cell holder and covered with the lid. Reading was then done and recorded.

Total Dissolved Solids (TDS)

A glass fiber disc was prepared by putting it on a membrane filter, and vacuum was applied to it. A clean dish was heated at 120°C for one hour in an oven and allowed to cool in a desiccator. The disc was weighed and noted before being used. The water samples in the plastic bottles were vigorously shaken. One-hundred milliliters of the water sample was transferred into a volumetric flask through a graduated measuring cylinder. The sample was filtered through the glass fiber disc using a suction pump. The total filtrate was moved to a previously weighed evaporating dish and evaporated to dryness on a water bath. The sample was dried for 2 hours and cooled in a desiccator, and the constant weight was calculated. The drying cycle was repeated until weight loss was less than 0.0005 g. The value was counted using the formula below.

\[
\text{TDS (mg/L)} = \frac{(A-B)}{C} \times 10^6
\]

Where,
- A = weight of residue + dish
- B = weight of dish
- C = Volume of water sample

Dissolved Oxygen (DO) by the sensor method

The electrode end of the DO meter was dipped into the water on the area. The temperature of the water was taken at the same time.

Biochemical Oxygen Demand (BOD)

BOD was determined immediately after determining the DO content. This process was carefully done to prevent air bubbles and by tilting the BOD bottles and gradually submerging it into the water. The bottle was allowed to overflow and covered with a stopper. Each bottle was kept in an ice chest and transported to the laboratory. In the laboratory, the BOD bottles were held in the dark cupboard to prevent light from getting in contact with the containers and their content for five days. The DO of the water was calculated with the same meter after the fifth day. The difference in DO between day one and day five marked the BOD.

\[
\text{BOD in mg/L} = \text{DO}_1 - \text{DO}_5
\]

Nitrate (NO₃⁻)

Cadmium Reduction Method measured nitrate level in each sample using Nitrate Powder Pillows in direct reading Hach Spectrophotometer Model DR. 2010. Ten mL of the sample were placed into the sample cell of the Spectrophotometer and added with one Nitraver 5 Nitrate Reagent powder pillow. The solution was shaken, then placed in the cell holder to determine the nitrate concentration in mg/L at 500 nm.

\[
\text{Phosphate (PO₄³⁻)}
\]

Ten mL of the water sample was placed in the sample cell. Phos Ver 3 Phosphate pillow was added to the cell content and immediately swirled to mix. The mixture was allowed to settle. The spectrophotometer displayed the results in mg/L PO₄³⁻ at 890 nm reading.

Sulfate (SO₄²⁻)

100 mL of the water sample was placed into a 250 mL Erlenmeyer flask, and 5 mL of conditioning reagent was added and mixed by stirring. One g of BaCl₂ was added and shaken for 60 seconds. The reading was carried out at a wavelength of 420 nm.

Determination of heavy metals in water samples

Concentrated HNO₃ (5 mL) was added into 100 mL of a water sample and evaporated on a hot plate to the lowest volume before precipitation occurs. Digestion was completed after the appearance of the clear light-colored solution. The solution was filtered through 0.45 µm filter paper and moved into a flask, cooled and top to the mark for analysis. The concentration of Copper (Cu), Cadmium (Cd), Arsenic (As), lead (Pd), and Zinc (Zn) were determined using 240 FS Atomic Absorption Spectrometer by direct aspiration of water samples into an air-acetylene flame and all into nitrous oxide-acetylene flame.

Sediment

Sample collection

Sediments from the sampling sites were collected under the aqueous layer using a trowel. The residue was placed in a plastic container and kept in an ice chest prior transported to the laboratory for analysis.

Sediment digestion and analysis

Sediment samples (0.4 g) were digested in Teflon tubes. Four mL of concentrated nitric acid (HNO₃) was added to the content slowly. The tubes were sealed and placed in
stainless steel bombs, then put on a hot plate and heated at 150 °C for 7 hours followed by cooling down to ambient temperature before carefully opening the bombs to release pressure. The samples were moved into the graduated polypropylene tubes, and the Teflon tubes were rinsed three times with distilled water then added to the content of the polypropylene tube. The material was diluted to the 50 mL mark of the machine with distilled water and mixed well. Determination of heavy metals from sediments was carried out using the cold vapor atomic absorption according to Milner and Whiteside (1981).

Social survey
Sociological data and other relevant information on the ethnobotanical use of aquatic plants and their effects on inhabitants' livelihood were investigated using questionnaire. One-hundred twenty questionnaires were conveniently administered to targeted members within the two communities from 25th of February to the 6th of March 2015. Targeted members included fishers and women, farmers, travelers on the lake, Traders along the lake and other community members very close to the lake. All respondents were 18 years and above. Questions were created based on background information and general information on the lake and aquatic plants. The objective was to assess inhabitant's perception on the use of aquatic plants in feeding animals within the communities. Sixty questionnaires were administered in each community.

Statistical analysis
The data were subjected to single factor analysis of variance (ANOVA) using SPSS software package version 16 for windows. Differences were declared significant at p ≤ 0.05 and means found to be significantly different were separated using the least significant difference LSD (Post hoc test) at p ≤ 0.05. The analyzed data were expressed as means with their standard deviation (X±SD).

Experimental precautions
All glassware was thoroughly cleaned before use. (i) Identifiable and fixed landmarks were used to locate the same spot for sampling throughout the study. (ii) Plant samples for phytochemical analysis were air dried at ambient temperature. (iv) BOD bottles were used to collect water for BOD calculation. (v) The bottles were carefully filled to the brim to remove air bubbles.

RESULTS AND DISCUSSION

Proximate analysis of the plant samples
Moisture content
The average moisture content of the plant is shown in Table 1. The result ranged from a minimum of 3.1% in T. australis to a maximum of 19.6% in I. aquatica. Analysis of variance (ANOVA) showed a significant difference of moisture content at 95% family. The Least significant difference (LSD) multiple comparison tests showed that there was no significant difference between the average between T. australis, S. cubensis and N. lotus but they were however significantly different from I. aquatica. The mean

<table>
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<th>Aquatic plants</th>
<th>Moisture (%)</th>
<th>Ether extract (%)</th>
<th>Crude protein (%)</th>
<th>Crude NFE (%)</th>
<th>Ash (%)</th>
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<td>0.70</td>
<td>1.16</td>
<td>1.42</td>
<td>2.68 1.41</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aquatic plants</th>
<th>Na (mg/L)</th>
<th>Ca (mg/L)</th>
<th>K (mg/L)</th>
<th>P (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. lotus</td>
<td>0.10</td>
<td>0.35</td>
<td>0.23</td>
<td>0.11</td>
</tr>
<tr>
<td>Max</td>
<td>0.23</td>
<td>0.45</td>
<td>0.43</td>
<td>0.20</td>
</tr>
<tr>
<td>Mean</td>
<td>0.16</td>
<td>0.40</td>
<td>0.33</td>
<td>0.16</td>
</tr>
<tr>
<td>S.e</td>
<td>0.06</td>
<td>0.05</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>I. aquatica</td>
<td>Min</td>
<td>0.20</td>
<td>0.02</td>
<td>0.23</td>
</tr>
<tr>
<td>Max</td>
<td>0.32</td>
<td>0.41</td>
<td>0.43</td>
<td>0.34</td>
</tr>
<tr>
<td>Mean</td>
<td>0.28</td>
<td>0.31</td>
<td>0.33</td>
<td>0.23</td>
</tr>
<tr>
<td>S.e</td>
<td>0.07</td>
<td>0.11</td>
<td>0.10</td>
<td>0.11</td>
</tr>
<tr>
<td>T. australis</td>
<td>Min</td>
<td>0.21</td>
<td>0.21</td>
<td>0.16</td>
</tr>
<tr>
<td>Max</td>
<td>0.30</td>
<td>0.34</td>
<td>0.27</td>
<td>0.20</td>
</tr>
<tr>
<td>Mean</td>
<td>0.25</td>
<td>0.28</td>
<td>0.22</td>
<td>0.17</td>
</tr>
<tr>
<td>S.e</td>
<td>0.05</td>
<td>0.07</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>S. cubensis</td>
<td>Min</td>
<td>0.31</td>
<td>0.23</td>
<td>0.28</td>
</tr>
<tr>
<td>Max</td>
<td>0.43</td>
<td>0.43</td>
<td>0.32</td>
<td>0.65</td>
</tr>
<tr>
<td>Mean</td>
<td>0.36</td>
<td>0.33</td>
<td>0.31</td>
<td>0.54</td>
</tr>
<tr>
<td>S.e</td>
<td>0.06</td>
<td>0.10</td>
<td>0.02</td>
<td>0.19</td>
</tr>
</tbody>
</table>
The average percentage ether extract of the plant samples from Ada fell from 6.3% in *S. cubensis* to 9.9% in *I. aquatica*. ANOVA at 95% family-wise confidence level showed that the percentage of ether extract in the various plant samples showed no significant difference (P>0.05). However, *I. aquatica* shows a higher variation in percentage ether extract, followed by *N. lotus*, *T. australis* and *S. cubensis*.

The average percentage ether extract of the plant sample from Kpong, however, ranged from 5.5% in *S. cubensis* to 12.4% in *I. aquatica*. ANOVA at 95% family-wise confidence level indicated that the percentage of ether extract in the various plants' samples was statistically significant (P<0.05). However, the LSD revealed that the means of *T. australis*, *S. cubensis*, and *N. lotus* are not significantly different, but there were however considerably different from *I. aquatica*.
Ash content

The average percentage ash content of the plant sample from Ada ranged from 6.3% in *T. australis* to 11.3% in *N. lotus*. *S. cubensis* and *I. aquatica* also documented an ash content of 7.0% and 8.9% respectively. Analysis of variance (ANOVA) at 95% family-wise confidence level showed that the ash content in the sampled plants was not statistically significant (P>0.05).

The average percentage ash content of the plant sample from Kpong also ranged from 8.6% in *S. cubensis* to 13.9% in *N. lotus*. Analysis of variance (ANOVA) at 95% family-wise confidence level suggested that the ash content in the sampled plants was statistically significant. The least significant difference, however, showed that there was no significant differences in the average between *T. australis*, *S. cubensis* and *I. aquatica* but each was significantly different from *N. lotus*. The average percentage ash content in the studied plants in decreasing order are as follows: *N. lotus* > *I. aquatica* > *T. australis* > *S. cubensis*.

Crude fibre

The average percentage crude fiber content of the plant sample from Ada ranged from 14.5% in *S. cubensis* to 20.4% in *I. aquatica*. The *T. australis* and *N. lotus* also showed crude fiber content of 15.1% and 16.5% respectively. Analysis of variance (ANOVA) at 95% family-wise confidence level showed that the crude fiber content in the sampled plants was not statistically significant (P>0.05).

The average percentage crude fiber content of the plant sample from Kpong also ranged from 11.8% in *S. cubensis* to 22.2% in *I. aquatica*. The *T. australis* and *N. lotus* also demonstrated crude fiber content of 13.1% and 15.6% respectively. Analysis of variance (ANOVA) at 95% family-wise confidence level indicated that the crude fiber content in the sampled plants differs significantly (P<0.05). The least significant difference revealed that there were no significant differences in means between *S. cubensis*, *T. australis*, and *N. lotus* but there were yet significantly different from *I. aquatica*.

Nitrogen-free extract

The average percentage NFE content of the plant sample from Ada ranged from 26.2% in *I. aquatica* to 52.0% in *S. cubensis*. The *T. australis* and *N. lotus* also showed mean NFE content of 48% and 46% respectively. ANOVA at 95% family-wise confidence level showed that the NFE content in the sampled plants was not statistically significant (P>0.05).

The average percentage NFE content of the plant sample from Kpong also ranged from 19.2% in *I. aquatica* to 55.7% in *S. cubensis*. The *T. australis* and *N. lotus* also showed mean NFE content of 47.3% and 36.9% respectively. Analysis of variance (ANOVA) at 95% family-wise confidence level indicated that the NFE content in the sampled plants was highly statistically significant. The least significant difference revealed that there were no substantial differences in the average of NFE between *T. australis* and *S. cubensis* but was yet different from and *N. lotus* and *I. aquatica*. The average percentage NFE content in the studied plants in a decreasing order of value are as follows: *S. cubensis* > *T. australis* > *N. lotus* > *I. aquatica*.

Crude protein

The average percentage crude protein content of the plant sample from Ada ranged from 14% in *S. cubensis* to 20% in *I. aquatica*. The *N. lotus* and *T. australis* also showed mean percentage crude protein content of 16.5% and 15.1% respectively. ANOVA at 95% family-wise confidence level revealed that the crude protein content in the sampled plants was not statistically significant (P>0.05).

The average percentage crude protein content of the plant sample from Kpong also ranged from 13.9% in *I. aquatica* to 22.7% in *T. australis*. The *N. lotus* and *S. cubensis* also showed mean percentage crude protein content of 16.6% and 15.6% respectively. ANOVA at 95% family-wise confidence level indicated that the crude protein content in the sampled plants was statistically significant (P<0.05) The LSD, however, showed that there were no significant differences in the average of crude protein among *S. cubensis*, *N. lotus*, and *I. aquatica* but were somehow significantly different from *T. australis*.

Mineral composition

The sodium levels in plants sampled at Ada sampling location fell from 0.10-0.23 mg/L, 0.20-0.32 mg/L, 0.21-0.30 mg/L and 0.31-0.43 mg/L for *N. lotus*, *I. aquatica*, *T. australis*, and *S. cubensis* respectively whilst that sampled at Kpong sampling location fell from 0.01-0.16 mg/L, 0.16-0.23 mg/L, 0.10-0.23 mg/L and 0.23-0.43 mg/L for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis* respectively.

The calcium levels in plants taken at Ada sampling location fell from 0.35-0.45 mg/L, 0.20-0.41 mg/L, 0.21-0.34 mg/L and 0.20-0.46 mg/L for *N. lotus*, *I. aquatica*, *T. australis*, and *S. cubensis* respectively whereas that atken at Kpong sampling location fell from 0.27-0.41 mg/L, 0.41-0.56 mg/L, 0.32-0.56 mg/L and 0.46-0.65 mg/L for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis* respectively.

The potassium levels in plants taken at Ada sampling location fell from 0.10-0.23 mg/L, 0.23-0.43 mg/L, 0.16-0.27 mg/L and 0.28-0.32 mg/L for *N. lotus*, *I. aquatica*, *T. australis*, and *S. cubensis* respectively whereas that sampled at Kpong sampling location fell from 0.19-0.43 mg/L, 0.42-0.51 mg/L, 0.34-0.52 mg/L and 0.12-0.32 mg/L for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis* respectively.

The phosphorus levels in plants taken at Ada sampling location also fell from 0.11-0.20 mg/L, 0.11-0.34 mg/L, 0.14-0.20 mg/L and 0.31-0.65 mg/L for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis* respectively whereas that sampled at Kpong sampling location fell from 0.03-0.11 mg/L, 0.11-0.21 mg/L, 0.05-0.16 mg/L and 0.54-0.67 mg/L for *N. lotus*, *I. aquatica*, *T. australis* and *S. cubensis* respectively.

Heavy metal concentration in plant samples

All the six heavy metals that were selected were detected in the plant samples both at Ada sampling site and Kpong sampling sites. These metals include copper (Cu), Zinc (Zn), Cadmium (Cd), Arsenic (As) and Lead (Pb).
The copper concentration in plants sampled at Ada sampling site ranged from 2.3-3.45 mg/L, 0.45-0.57 mg/L, 0.34-0.45 mg/L and 0.23-0.25 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively whilst that sampled at Kpong sampling sites ranged from 0.261-6.41 mg/L, 0.26-0.43 mg/L, 0.17-0.6 mg/L and 0.08-0.12 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively.

The arsenic concentration in plants sampled at Ada sampling site ranged from 0.01-0.18 mg/L, 0,02-0.19 mg/L, 0.23-0.28 mg/L and 0.01-0.23 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively whilst that sampled at Kpong sampling sites ranged from 0.01-0.06 mg/L, 0.06-0.20 mg/L, 0.14-0.20 mg/L and 0.16-0.34 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively.

The zinc concentration in plants sampled at Ada sampling site ranged from 1.65-2.0 mg/L, 0.13-0.23 mg/L, 0.20-0.32 mg/L and 0.05-0.19 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively whilst that sampled at Kpong sampling sites ranged from 0.72-2.81 mg/L, 0.06-0.21 mg/L, 0.26-0.42 mg/L and 0.25-0.63 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively.

The Cadmium concentration in plants sampled at Ada sampling site ranged from 0.07-0.16 mg/L, 0.14-0.17 mg/L, 0.13-0.32 mg/L and 0.36-0.52 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively whilst that sampled at Kpong sampling sites ranged from 0.08-0.15 mg/L, 0.10-0.13 mg/L, 0.13-0.23 mg/L and 0.32-0.47 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively.

The lead concentration in plants sampled at Ada sampling site ranged from 0.57-0.75 mg/L, 0.23-0.30 mg/L, 0.17-0.23 mg/L and 0.25-0.38 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively whilst that sampled at Kpong sampling sites ranged from 0.67-0.96 mg/L, 0.06-0.21 mg/L, 0.26-0.42 mg/L and 0.25-0.63 mg/L for N. lotus, I. aquatica, T. ausralis and S. cubensis respectively.

Physicochemical parameters of water
Temperature and pH

The water temperature sampled at Ada stretch of the river ranged from 28.4 to 30.2 °C with an average value of 29±0.9 °C, that of Kpong stretch of the river varied from 30.1-32.6 °C with an average temperature of 31.7±1.0 °C whilst that of Amendeda fell from 29.2-32.3 °C with a mean temperature of 30.9±8.6 °C.

Statistical analysis using ANOVA displayed that there were a statistically no significant differences in temperature between the three sampling locations (t=42.2, P<0.05) at 5% level of significance (95% family-wise confidence level).

Pearson’s product moment correlation matrix performed to determine the degree, direction, and strength of the interrelationship between the physicochemical parameters and heavy metal concentration in the water sample at the locations indicated that temperature had a strong significant positive relationship with cadmium with a correlation coefficient (r) of 0.854. There was, however, a weak correlation between temperature and the following metals Zn, Cu, Cr and As.

The water pH sampled at Ada stretch of the river ranged from a minimum of 6.8 to a maximum of 7.0 pH units with an average value of 6.9±0.1, that of Kpong ranged from 6.2-6.5 pH units with a mean pH of 6.37±0.2 and that of Amendeda range from 6.3 to 6.9 with a pH of 6.70±0.15.

Statistical analysis using ANOVA indicate no significant difference in the average of pH from the three sampling locations. Pearson’s product moment correlation matrix, nevertheless, showed that pH had a highly significant negative correlation with cadmium and zinc at 5% and 1% level of substantial respectively (pH-Cd, r=-0.776, P<0.05), pH-Cr, r=-0.669, P<0.01). There was, yet, a strong positive correlation between pH and Zn.

The DO in the water sampled at Ada fell from 17.6 mg/L to 19.2 mg/L with an average value of 18.4±0.8 mg/L. Meanwhile, the Kpong stretch of the river also ranged from 8.6 mg/L-12.7 mg/L with average 10.7±2.0 mg/L and that of Amendeda ranged from 22.3 mg/L to 26.6 mg/L with a mean DO value of 24.4±2.50 mg/L.

Statistical analysis using ANOVA indicates a significant difference in means of DO from the three sampling sites. Pearson’s product moment correlation matrix stated that there was generally a weak correlation between DO and the studied metals; however, DO have a strong positive relationship with zinc with a correlation coefficient of r=0.770 and a negative correlation with cadmium with a correlation coefficient of r=-0.805 at 5% level of significance.

The BOD in the water sampled at Ada ranged from 6.5 mg/L to 8.4 mg/L with an average value of 7.5±0.9 mg/L, that of Kpong ranged from 1.6 mg/L-4.5 mg/L with an average value of 3.1±1.4 mg/L and that of Amendeda ranged from 0.93 mg/L to 1.87 mg/L with an average DO of 1.13±0.21 mg/L. ANOVA test ranged revealed that there were no statistically significant differences in dissolved oxygen between the water at Kpong and Amendeda. There was, however, a statistically significant difference in dissolved oxygen content between (Kpong and Amendeda) and (Amendeda and Kpong).

Pearson’s product moment correlation matrix revealed that BOD negatively correlates with cadmium and Zinc. (BOD-Cd, r=-0.831, P<0.05), (BOD-Zn,r=-0.763,P<0.05).

Nitrate, sulfate, and phosphate

The nitrate level of the water sampled at Ada stretch of the river ranged from 1.25 mg/L to 1.84 mg/L with an average value of 1.47±0.3 mg/L, that of Kpong ranged from 2.2-2.4 mg/L with an average value of 2.3±0.1 mg/L and that of Amendeda ranged from 0.76 mg/L to 1.23 mg/L. ANOVA revealed no statistical difference between water from Amendeda and Ada sampling locations, but a significant difference was shown between (Amendeda and Kpong) and (Ada and Kpong) sampling locations (P<0.05).

The sulfate concentration of the water sampled at Ada stretch of the river recorded an average value of 4 mg/L, that of Kpong fell from 5-6 mg/L with an average value of...
Results of heavy metal analysis in water and sediment

Heavy metals detected at the three sampling sites include copper (Cu), lead (Pb), Cadmium (Cd), Arsenic (As), and Zinc (Zn). The total heavy metals concentrations in sediments and water at Ada sampling location fell from (3.73-4.82 mg/L, 0.34-0.50 mg/L), (0.44-0.49 mg/L, 0.1-0.2 mg/L), (1.2-1.7 mg/L, 0.02-0.06 mg/L), (6.8-8.5 mg/L, 0.14-0.19 mg/L), (0.9-3.2 mg/L, 0.01-0.03 mg/L) and 0.9-1.5 mg/L, 0.01-0.02 mg/L for copper (Cu), Zinc (Zn), lead (Pb), Chromium (Cr), Cadmium (Cd), and Arsenic (As) respectively. The total heavy metal level in sediment and water sample at Kpong sampling locations also fell from 4.6-5.7 mg/L, 0.38-0.46 mg/L (Cu), 0.4-0.5 mg/L, 0.112-0.113 mg/L (Pb), 0.5-0.9 mg/L, 0.05-0.06 mg/L (Cr), 0.9-2.5 mg/L, 0.05-0.06 mg/L (Cd), 5.3-6.8 mg/L, 0.09-0.14 mg/L (Zn) and 0.14-0.6 mg/L, 0.01-0.04 mg/L (As). The control site (Amedaka sampling location), however, recorded very low levels of heavy metal level in the sediments and water. It fell from (0.8-1.2 mg/L, 0.35-0.41 mg/L), (0.1-0.18 mg/L, 0.01-0.02), (0.9-1.2 mg/L, 0.2-0.3), (4.1-4.8 mg/L, 1.2-1.3), (0.1-1.5 mg/L, 0.01-1.2 mg/L) and 0.2-0.8 mg/L, (0.01-0.04 mg/L for copper (Cu), Cadmium (Cd), lead (Pb), Zinc (Zn) and Arsenic (As) respectively. The average values and the standard deviations of the heavy metals concentration are illustrated in Table 8.

Table 8. Mean values of heavy metals (mg/L ±SD) in sediment samples at the study area

<table>
<thead>
<tr>
<th>Site</th>
<th>Cd</th>
<th>As</th>
<th>Pb</th>
<th>Cr</th>
<th>Zn</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ada</td>
<td>2.3±1.2</td>
<td>1.2±0.3</td>
<td>0.47±0.02</td>
<td>1.4±0.25</td>
<td>7.5±0.86</td>
<td>2.3±1.2</td>
</tr>
<tr>
<td>Kpong</td>
<td>1.8±0.8</td>
<td>0.3±0.02</td>
<td>0.4±0.03</td>
<td>0.7±0.025</td>
<td>80±0.8</td>
<td>1.8±0.8</td>
</tr>
<tr>
<td>Amedaka</td>
<td>0.8±0.02</td>
<td>0.1±0.01</td>
<td>0.2±0.001</td>
<td>0.4±0.001</td>
<td>2.3±0.02</td>
<td>1.2±0.03</td>
</tr>
</tbody>
</table>

Table 10. Comparison between the mean concentration of trace metals in water and sediment

<table>
<thead>
<tr>
<th>Site</th>
<th>Sample</th>
<th>Parameter</th>
<th>Cd</th>
<th>As</th>
<th>Pb</th>
<th>Cr</th>
<th>Zn</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ada</td>
<td>Water</td>
<td>F</td>
<td>7.5</td>
<td>24.1</td>
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<td>51.4</td>
<td>118.7</td>
<td>7.5</td>
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<td>Sediment</td>
<td>P-value</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>1.01ns</td>
</tr>
<tr>
<td>Kpong</td>
<td>Water</td>
<td>F</td>
<td>8.5</td>
<td>32.3</td>
<td>185.9</td>
<td>47.2</td>
<td>114.3</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>Sediment</td>
<td>P-value</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.30ns</td>
</tr>
<tr>
<td>Amedaka</td>
<td>Water</td>
<td>F</td>
<td>7.2</td>
<td>25.8</td>
<td>175.3</td>
<td>49.5</td>
<td>117.5</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>Sediment</td>
<td>P-value</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.00*</td>
<td>0.20ns</td>
</tr>
</tbody>
</table>

P<0.05 probability level; ns: Not significant

Table 9. Pearson’s product moment Correlation between physicochemical parameters and heavy metals in sediments

<table>
<thead>
<tr>
<th>VAR</th>
<th>pH</th>
<th>Temp</th>
<th>Cu</th>
<th>AS</th>
<th>Pb</th>
<th>Cr</th>
<th>Zn</th>
<th>Cd</th>
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</thead>
<tbody>
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<td>pH</td>
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<td>0.543*</td>
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<td>0.722*</td>
<td>-0.960*</td>
<td></td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>0.558</td>
<td>0.692*</td>
<td>3.935**</td>
<td>3.719*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>1</td>
<td>0.358</td>
<td>0.538</td>
<td>0.692*</td>
<td>0.722*</td>
<td>0.960*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>As</td>
<td>1</td>
<td>3.935**</td>
<td>3.719*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>1</td>
<td>0.632*</td>
<td>1.662*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td>1</td>
<td>0.632*</td>
<td>1.662*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd</td>
<td>1</td>
<td>0.632*</td>
<td>1.662*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Correlation between physico-chemical parameters and heavy metals in sediments

Considerable numbers of significant positive and adverse correlation were observed between the following physicochemical variables and heavy metals level in the sediment sample; Temperature and Cadmium (r=-0.960, P<0.01), Temperature and Zinc (r=-0.722, P<0.05), pH and Cr (r=-0.543, P<0.05), As and Zn (r=0.719, P<0.05), Cr and As (r=0.935, P<0.01), Pb and Cd (r =-0.632,P<0.05). Table 9 displays the person’s product moment correlation matrix of the significant physicochemical and heavy metal level in sediments of the lower Volta basin.

Table 11. Results of the phytochemical analysis of four aquatic plants

<table>
<thead>
<tr>
<th>Phytochemicals</th>
<th>Nymphaea lotus</th>
<th>Ipomoea aquatica</th>
<th>Typha australis</th>
<th>Scirpus cubensis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaloids</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Flavonoids</td>
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<td>Saponins</td>
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<td>Sterols</td>
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<td>Phenols</td>
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<td>Proteins</td>
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<td>Terpenoids</td>
<td>+</td>
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Note: All experiments were done in triplicate. Legend: + = Present, - = Absent.
Phytochemical screening

Results obtained from the qualitative screening of plant samples are indicated in Table 11. Of the seven phytochemicals analyzed, three were found in all the four plants samples; saponins, flavonoids, and phenols. *N. lotus* possessed all the phytochemicals tested present. Alkaloids and proteins were not identified in *I. aquatica*. Terpenoids were not present in *T. australis*. Sterols were not present in *S. cubensis*.

Social survey

A questionnaire was given to 120 individuals within chosen communities in the study area, Kpong (50%) and Ada (50%). Concerning the sex of the individuals, 71 individuals were males whilst 49 individuals were females.

Forty-seven people were between the ages of 20-29 years, 30%, 20.8% were between the ages of 30-39 and 40-49 respectively whereas only 10% were 50 years and above at the time the interview was sought.

Similarly, thirty-five of the respondent engage in fishing whilst 28.3% participate in various trading activities with 11.7%, 10% and 15% participating in farming, office work, and handwork respectively.

The results showed that about 47% of the respondents were indigenous whilst 53% were settlers. The educational degree of the respondents was sought, and it demonstrated that 39.2% of the community had JSS education whilst 15% had secondary/6th form education, Ten percent (10%) had a tertiary education with 1.7% having vocational, 34.2% had no formal training.

On the possible use of the river, 48 individuals use the water for domestic activities whereas 36.7% use the water for fishing. Nevertheless, 11.7% and 10.8% use the water for irrigation and swimming respectively.

When the respondents were questioned whether the plants that grow at the sampling sites are used to feed their animals, 65.2% of them answered in the affirmative whilst the rest said they don't use the plants to feed animals.

Similarly, 67.5% of the individuals attested to the fact that the plants harvested imposed medicinal value whilst the remaining respondents thought the opposite. When the perspectives of the respondents were sought to ascertain whether the plants are the habitat of some wild animals including snakes, 92.3% answered in the affirmative. However, most of the respondents had not been bitten by those snakes during the use of the water for their various activities.

When the respondents were questioned whether they fish in regions densely populated with weeds, 32.7% of them answered in the affirmative whilst the rest said they do not fish in such areas. The respondents similarly confirmed that the abundance of weeds had decreased their fish catch as majority representing 79.2% answered in the affirmative.

On the possible utilization of the water for drinking purposes, 43.3% of the individuals drink the water directly from the river whereas the remaining 56.7% use other sources such as wells and borehole as a significant source of drinking water. However, this same water used by humans is also an excellent source of drinking water for animals such as cattle, sheep, goats, and pigs as 74.2% of the respondents affirmed to that fact.

When the respondents were questioned whether the abundance of weeds had raised the cost of transportation on the river, 54.2% replied in the affirmative whilst 45.8% said it had not raised the cost of shipping. The respondents noted that the vector-borne disease that is currently prevalent in the area is malaria as opposed to Schistosomiasis which was the significant disease in the area.

Also, 78% of the respondent confirmed that children no longer swim in densely infested locations. When the respondents were questioned which kind of livestock they have in their communities, 100% indicates the presence of cattle, goat, sheep, pigs, and poultry in their communities.

Discussion

*Nymphaea lotus* from Ada exhibited the highest ash content, a total mineral or inorganic material of the sample. This implies *N. lotus* has the highest of total mineral or inorganic content which may be vital to animals and subsequently humans. The other proximate constituents (crude fiber, protein, ether extract, ash, and nitrogen-free extract) were all higher than that of a fresh early bloom *Panicum maximum* from Tanzania. Higher protein content makes it appropriate for animal feed and as human feed. For this reason, many humans around the world feed on *N. lotus* (Nordeide et al. 1994). This trend was similar to that observed for *N. lotus* at Kpong. The findings obtained in the proximate analysis of *N. lotus* were identical to that found by Shah et al. (2010) in Srinagar. The crude protein content and nitrogen-free extracts of *N. lotus* are equal to that of Alfalfa hay (C.P= 16.91%, NFE= 40.55%) (Banerjee and Matia 1990).

The proximate constituents (crude protein, ash content, ether extract, and nitrogen-free extracts) of *I. aquatica* from Ada were higher than the corresponding components in a fresh early bloom *P. maximum* from Tanzania. The result implies that *I. aquatica* has a higher nutritional value than *P. maximum*. The high ash content of *I. aquatica* indicates that the plant contains the nutritionally important mineral element.

The crude protein content in *I. aquatica* was found to be higher than that reported in *I. aquatica* leaves found in Vietnam (Ogle et al. 2001). The crude fiber was, however, lower than that of *P. maximum*. The results showed a similar trend at Kpong.

*Typha australis* possessed the highest crude protein content that is comparable to that of *Azolla pinnata* (21.9%) and *Pistia stratiotes* (20.5%) (Banerjee and Maitai 1990) which is an edible underwater tuber. The crude protein content, ether extracts, and nitrogen-free extracts were higher than the corresponding materials in *P. maximum*. Ash content was lower in *T. australis* than *P. maximum* suggesting lower mineral or inorganic material in *T. australis*. The nutrient composition of *Typha australis* taken from Ada was more or less similar to the samples from Kpong.

*Scirpus cubensis* had the highest NFE indicating the presence of more digestible carbohydrates, vitamins and
other non-nitrogen soluble organic compounds which are crucial for animals and human growth. Ether extracts and Nitrogen free extracts were also higher than the corresponding constituents in *P. maximum*. Crude fiber and ash content were higher in *P. maximum* than *S. cubensis*.

The variation of the mineral composition of the four aquatic plants may be due to differences in the genus and species level of the plants (Kalita et al. 2007). Among the four species, *S. cubensis* showed a relatively higher mineral content. Calcium and phosphorus were unusually high in *S. cubensis* at Ada. Non-availability of adequate quantities of minerals in the diet affects animal growth and may cause irrecoverable deficiency diseases (De Silva and Anderson 1994).

All heavy metals analyzed in the plants were lower than the standard set by WHO/FAO. 2007 for metals in foods and vegetables. Among the species studied, Zinc and Copper were unusually high in *N. lotus*, perhaps due to the natural abundance of this element in the environment. Besides, the broad nature of the leaves of *N. lotus* gives the plant a sufficient surface area to absorb metals from the water. The presence of relatively higher content of Copper and Zinc in *N. lotus* makes it more considerable to be incorporated in the animal diet because it will provide the animals with essential trace elements.

All the plant species except *I. aquatica* have proteins, suggesting that they can be utilized feed for animals their overgrowth as weeds. The presence of the secondary metabolites indicates that the plants are potential sources of pharmaceutical agents. This is because secondary metabolite derived from the plant have been shown to possess pharmacological activities and also are involved in disease cure, prevention and general health of the human body as demonstrated by the folkloric use of plant parts for medicinal purposes.

The average temperature of water sampled at Ada and Kpong was similar to the control site (Amedeka). However, there was a slight difference in temperature at the sampling sites. The small differences in temperature could be due to the natural occurrence in the water as sulfur occur naturally in its reduced form in igneous and sedimentary rocks (Singleton 2000). The sulfate concentration at the three sampling points was however within the WHO guideline of sulfate in drinking water (10 mg/L).

Nitrate levels at Ada and Kpong were higher than the standard applied by WHO for drinking water. The nitrate grossly exceeded the total average of 0.1 mg/L of nitrate in freshwater bodies (Meybeck and Helmer 1989), perhaps could be as a result of runoff from fertilized farmlands and domestic waste. This partly accounts for the high nitrate levels at infested areas of aquatic plants. The nitrate levels of the water at the three sampling sites were, however, fell within the WHO guideline of nitrate in drinking water (10 mg/L).

The low DO record at Ada and Kpong reflect the high number of living organisms the plant in the water. On the field, the flow rate of water within infested areas was impeded by the aquatic plants. DO is affected by flow rate, mixing and aeration due to wind action (Straskaba and Tundisi 1999). However, the DO levels recorded at the two sampling sites were higher than the WHO standards for drinking water (7.5 mg/L), indicating that the waterbody is much oxygenated despite the presence of the numerous aquatic plants.

BOD values measured for Ada and Kpong were higher than that of the control. Moderately polluted rivers show a BOD that falls in the range of 2-8 mg/L (Thakre et al. 2010). The BOD values recorded at two locations above fell within the scope of a moderately polluted water body. Thus, it implies that the aquatic plants exert some level of pollution on water. The BOD value of water in the control area was below the range of pollution (1.13 mg/L). Asante et al. (2008) mentioned an average BOD value of 4.5 mg/L on the Weija Reservoir and Karikari et al. (2013) also described a BOD value of 3.5 mg/L on the Volta River which agrees with this study.

Nitrate levels at Ada and Kpong were higher than nitrate levels at the control location. Nutrient levels were usually low in the waterbody of the study area. However, the nitrate grossly exceeded the total average of 0.1 mg/L of nitrate in freshwater bodies (Meybeck and Helmer 1989), perhaps could be as a result of runoff from fertilized farmlands and domestic waste. This partly accounts for the high nitrate levels at infested areas of aquatic plants. The nitrate levels of the water at the three sampling sites were, however, fell within the WHO guideline of nitrate in drinking water (10 mg/L).

The average concentration of sulfate in freshwater bodies is 4.8 mg/L (Meybeck and Helmer 1989). Sulfate concentration of water from Ada and the control site (Amedeka) fell below 4.8 mg/L. Sulfate concentration in water at Kpong was higher than the average sulfate concentration in freshwater. There was, however, no significant difference in means of sulfate concentration at the three sampling points. The level of sulfate in the water could be due to the natural occurrence in the water as sulfur occur naturally in its reduced form in igneous and sedimentary rocks. The sulfate concentration at the three sampling points was however within the WHO guideline of 250 mg/L for drinking water.

Aquatic plants in the study area have no significant influence on the phosphate concentration of the water. This result contradicts that of Mioronga et al. (2012) in Lake Naivasha that phosphate concentration in infested areas is lower than uninfested areas. The natural background reading of phosphate (P-PO43-) in inland waters usually range from 0.005 to 0.05 mg/L (Dunne and Leopold 1978), the mean PO43-contents at all the three sampling sites were outside the range. The result might be attributed to the washing of utensils, clothing, and bathing by children and adults in the river at each sampling area as witnessed during the study.

The turbidity values of the water taken at Kpong and Ada were higher than that of Amedeka which served as the
The current study has underlined that *N. lotus*, *I. aquatica*, *T. australis*, and *S. cubensis* could be significant sources of proteins and minerals suitable for incorporation into the animal diet. The results suggest that all the four plant species have higher nutritive value than *P. maximum*. Exploitation of these aquatic plants will not only of economic importance but also would be a step towards a sustainable and effective way of managing aquatic vegetation within the Lower Volta Basin.

*Nymphaea lotus*, *T. australis*, and *S. cubensis* have demonstrated the presence of phytochemicals, promising the nutritional and antioxidant properties. Harvesting these plants for animal fodder and medicinal use will drastically decrease the invasive effects of these weeds on the water body and also aid in the management of aquatic plants within the LVB.

Heavy metals concentration analyzed in the plants were found to be lower than the standard set by WHO/FAO, 2007 for metals in foods and vegetables. Copper and Zinc were relatively higher in *Nymphaea lotus* than in other plants. The high levels of copper and zinc in *N. lotus* makes it suitable to be added to the animal diet due to the vital role of copper and zinc animals.

The physicochemical parameters of water (pH, nitrates, DO, BOD) revealed that most of the parameters of water differed significantly from the control site. The concentrations of heavy metals in the waterfall within the WHO guideline for drinking water except for lead (Pb) and Cadmium (Cd). The measured levels of all the studied metals in the sediment samples were higher than the concentrations in the water columns. Heavy metals fractionation should be carried out to ascertain the concentrations of heavy metals in each fraction of the sediment.

From the survey, responses from the respondents suggested that some group of people use some of the plants particularly *N. lotus* to feed animals. Consistent harvesting of this plant will aid in the management of aquatic plants within the LVB.

**REFERENCE**


