BIOFARMASI J NAT PROD BIOCHEM
Volume 16, Number 2, August 2018 E-ISSN: 2580-2550
Pages: 99-112 DOI: 10.13057/biofar/f160205

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

WEMEGAH JOSHUA ETSE, TED Y. ANNANG♥, JESSE S. AYIVOR
Institute for Environmental and Sanitation Studies, University of Ghana, Legon. ♥email: tyannang@ug.edu.gh

Manuscript received: 7 July 2018. Revision accepted: 30 August 2018.

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 16: 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 Chemists (AOAC 2002). Water and sediment quality analyses of some physicochemical variables were also carried out using processes described in the standard water and wastewater examination methods. 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 significantly different from the control site. The level of heavy metals 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 suggest a high nutritional potential and indicate their possible use as mixed ingredients in animal feed. Exploiting these aquatic plants for animal feed would be a step towards better utilization of these plants to help manage 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 their environment's challenges. The aquatic vegetation can change the physicochemical characteristics of both water and hydrosoil, thereby altering water quality (Petosa et al. 2010). They can also provide habitat and food for the larval stage of animal vectors of human diseases such as malaria, posing 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 by severe aquatic macrophyte infestation, resulting 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 the Akosombo Dam in 1963 and the Kpong dam in 1981 had created an ideal situation for the quick growth of aquatic plants in the Lower Volta Basin of the Ghana (LVB). They 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*, and *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 with 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. However, the cost-benefit of this initiative is subject to much controversy because elsewhere in other parts 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 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). This research ultimately explores 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 using 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 that 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 sang sites were chosen (Kpong, Big Ada, and Amedeka). Ada and Kpong areas are the stretches on the Lower Volta heavily populated with diverse water plants. Water samples were brought from Amedeka, where there were no weeds, and served as a control site.

Brief description of the sampling sites

Kpong head pond

The surface area is about 37.4 km^{2}, 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 the 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 the family Typhaceae, common names as cattail, punks, reedmace, bulrus, corn dog grass, etc. The rhizomes are edible.

Typha is often found to colonize newly exposed wet mud areas with its abundant wind-dispersed seeds. Seeds can survive inside the soil for long periods. The seeds germinate best with sunlight and fluctuating temperatures, typical of many wetland plants that regenerate on mudflats. Rhizomes also spread Thypa, forming large, interconnected strands. It is considered the dominant competitor in wetlands in many regions, and it often eliminates other plant species with its large canopy. For instance, the Great Lakes bay 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 that float on the water and 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 Volta Lake (Wiersema 1982).

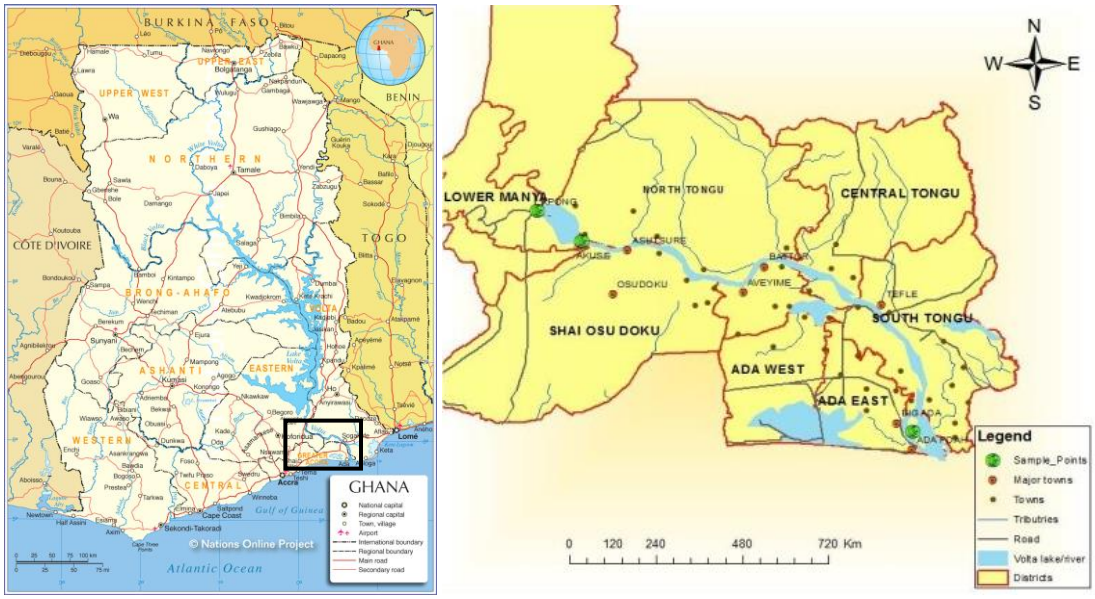

Figure 1. Map of the study area in Lower Volta Basin, Ghana

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. In English, this plant is called water spinach and increases in water or moist soil. They are hollow and can float. Propagation is either planting seeds from flowers or planting cuttings of the stem shoots that will root along with nodes (Prasad et al. 2008).

Scirpus cubensis Poeppig & Kunth

Scirpus cubensis is a leafy plant that 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 to data collection. Using appropriate protocols, plant, water, and sediment samples were analyzed quantitatively in the laboratory. Four different plant species, namely *N. lotus, T. australis, I. aquatica,* and *S. cubensis,* were taken from each sampling site 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. After the survey, two sampling sites were chosen using a judgment sampling technique 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^{o}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 were 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 the 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 were weighed into a thimble 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 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^{0}C for 4 hours, cooled in the desiccator, and weighed.

$$\%\text{Ether extract} = \frac{(\text{wt of flask + extract}) - (\text{tare wt of flask}) \times 100}{\text{wt of sample}}$$

Crude fiber

Crude fiber is determined by the organic residue left after sequential extraction of a sample with ether. The fat-free material was moved to a flask/beaker, 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 pouring hot water. The Buckner flask funnel is fitted with pre-heated Whatman filter paper. The boiled acid sample mixture was filtered through the funnel under sufficient suction, washed several times with boiled water (until the residue was neutral to litmus paper), and transferred back into the beaker. Following this step, 200 mL of pre-heated 1.25% sodium sulfate (Na_2SO_4) 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 ^{0}C for 24 hrs and measured. The residue was moved into a crucible and placed in a muffle furnace (400-600 ^{0}C) and ash for 4hrs, then cooled in a desiccator and weighed.

$$\%\text{Crude fiber} = \frac{\text{Dry wt of residue before ashing} - \text{wt of residue after ashing}}{\text{wt of sample}} \times 100$$

Crude protein

Crude protein was calculated using a Kjeldahl method involving digestion, distillation, and titration. The nitrogen content of the plant sample was measured and multiplied 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 a Kjeldahl flask, 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. After cooling down, one hundred mL of distilled water was rapidly added to the samples.

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

Titration: the alkaline ammonium borate created was titrated directly with 0.1N HCl. The volume of acid used was fitted into the formula below.

$$\%N = \frac{14 \times VA \times 0.1 \times w \times 100}{1000 \times 100}$$

Where:
VA = volume of acid used
w = weight of the sample
%N = Percentage nitrogen
%crude protein =%N x 6.25

Ash

Ash is the inorganic residue of the organic matter of a plant sample burnt in a muffle furnace at 400-600^{0}C for 4hrs. Two grams of the sample were weighed into a pre-heated crucible and later placed in the muffle furnace at 400-600 ^{0}C for 4hrs or until whitish-grey ash was obtained. The crucible was placed in the desiccator, allowed to cool, and weighed.

$$\%Ash = \frac{\text{wt of crucible+ash-wt of the crucible}}{\text{wt of sample}}$$

Nitrogen Free Extract (NFE)

NFE was determined by mathematical calculation by subtracting the sum of percentages of all the nutrients already calculated from 100.

$$\%NFE = 100 - (\%moisture + \%CF + \%CP + \%EE + \%Ash)$$

NFE represents soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in the feed.

Phytochemical screening

Dried plant samples were pulverized into powder. Five grams of the powdered material was dispersed in 50 mL of methanol. The solution was left to stand for 24 hrs and filtered with Whatman No. 1 filter paper. The filtrate was assessed for the phytochemical screening using the following tests.

Test for alkaloids (Wagner's reagent test)

A fraction of the extract was treated with 3-5 drops of Wagner's reagent (1.27 g of iodine and 2 g of potassium iodide in 100 mL of water) and observed for the formation reddish-brown precipitate or coloration.

Test for flavonoids (Alkaline reagent test)

Two mL of the extract was treated with a few 20% sodium hydroxide solution drops. The formation of intense yellow color, which becomes colorless with the addition of dilute hydrochloric acid, suggests the presence of flavonoids.

Test for phenols (Ferric chloride test)

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

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 showed a reddish-brown color that produced immediately indicated the presence of terpenoids.

Test for sterols (Liebermann-Burchard test)

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

Mineral analysis

One gram of the powdered sample was added with 25 mL of concentrated HNO_3 in a flask. The flask was then heated until the evolution of the brown fume stopped. The mixture was added with 1 cm^3 of perchloric acid and then heated to a clear solution. After that, 30 mL of hot distilled water was poured into 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. A 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 them 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 10ºC) 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 20 NTU (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 a vacuum was applied to it. A clean dish was heated at 120ºC 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 in 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.

$$TDS\ (mg/L) = (A-B) / Cx10^6$$

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 in 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 by tilting the BOD bottles and gradually submerging them 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. The BOD bottles were held in a dark cupboard to prevent light from contacting the containers and their content for five days in the laboratory. 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.

$$BOD\ in\ mg/L = DO_1 - DO_5$$

Nitrate (NO_3^-)

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.

Phosphate (PO_4^{3-})

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 PO_4^{3-}at 890 nm reading.

Sulfate (SO_4^{2-})

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 $BaCl_2$ 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 to 100 mL of a water sample and evaporated on a hot plate to the lowest volume before precipitation occurred. 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

Using a trowel, sediments from the sampling sites were collected under the aqueous layer. The residue was placed in a plastic container and kept in an ice chest before being 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 (HNO_3) was added to the content slowly. The tubes were sealed and placed in stainless steel bombs, then put on a hot plate and heated at150 ºC for 7 hours, then cooled 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 and 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 a questionnaire. One hundred twenty questionnaires were conveniently administered to targeted members within the two communities from the 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 the inhabitant' perception of 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 version 16 for windows. Differences were declared significant at $p \leq 0.05$, and means found to be significantly different were separated using the least significant difference LSD (Post hoc test) at $p \leq 0.05$. 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 moisture content difference at 95% family. The Least significant difference (LSD) multiple comparison tests showed no significant difference between the average between *T. australis, S. cubensis,* and *N. lotus.* Still, they were however significantly different from *I. aquatica*. The mean moisture content of ranking are as follows; *I. aquatica* > *N. lotus* > *S. cubensis* > *T. australis.* The average moisture content in the plant samples from Kpong also ranged from 2.1% in T. australis to 19.1% in *I. aquatica*. The analysis data show similar trends to the plants sampled at Ada.

Table 1. Nutritional composition of aquatic plants from Ada

Aquatic plants		Moisture (%)	Ether extract (%)	Crude protein (%)	Crude fiber (%)	NFE (%)	Ash (%)
N. lotus	Min	4.50	4.5	13.45	9.78	41.07	9.70
	Max	7.90	14.75	20.10	20.13	55.52	12.56
	Mean	6.30	8.08	15.17	16.53	46.06	11.27
	S.e	1.70	5.78	3.62	5.84	8.20	1.45
I. aquatica	Min	15.67	3.20	11.23	17.87	22.11	6.54
	Max	23.45	13.67	17.98	23.78	37.74	12.45
	Mean	19.56	9.92	14.96	20.40	26.20	8.95
	S.e	1.71	5.83	3.43	3.04	4.64	3.10
T. australis	Min	3.10	3.45	19.78	9.78	43.07	4.50
	Max	3.20	11.56	20.23	17.89	54.41	8.86
	Mean	3.17	7.27	20.04	15.15	48.06	6.32
	S.e	0.06	4.08	0.23	4.65	5.79	2.32
S. cubensis	Min	2.20	5.6	11.45	7.98	45.59	4.50
	Max	9.40	7.67	18.64	19.87	61.07	8.86
	Mean	5.37	6.29	16.53	14.51	52.24	7.09
	S.e	3.68	1.20	3.39	6.03	7.09	2.32

Table 2. Nutritional composition of aquatic plants from Kpong

Aquatic plants		Moisture (%)	Ether extract (%)	Crude protein (%)	Crude fiber (%)	NFE (%)	Ash (%)
N. lotus	Min	6.20	5.63	15.10	13.60	31.41	12.31
	Max	7.10	6.31	18.62	17.76	40.53	15.32
	Mean	6.60	6.05	16.68	15.69	36.91	19.96
	S.e	0.45	0.36	1.79	2.08	4.84	1.53
I. aquatica	Min	17.63	11.62	12.30	19.64	10.15	9.63
	Max	20.36	13.16	15.63	24.30	25.64	10.73
	Mean	19.14	12.40	13.92	22.19	19.29	10.06
	S.e	1.39	0.77	1.67	2.36	8.11	0.59
T. australis	Min	1.80	5.30	18.43	11.61	45.40	6.32
	Max	2.60	6.21	26.30	14.63	49.32	12.31
	Mean	2.17	5.40	22.78	13.15	47.37	8.78
	S.e	0.41	0.80	4.0	1.51	1.96	3.14
S. cubensis	Min	1.80	4.70	14.30	10.20	52.89	6.32
	Max	3.20	6.30	16.32	12.70	58.20	12.31
	Mean	2.53	5.54	15.64	11.84	55.77	8.67
	S.e	0.70	0.80	1.16	1.42	2.68	1.41

Table 3. Mineral composition in plant samples from Ada

Aquatic plants		Na (mg/L)	Ca (mg/L)	K (mg/L)	P (mg/L)
N. lotus	Min	0.10	0.35	0.23	0.11
	Max	0.23	0.45	0.43	0.20
	Mean	0.16	0.40	0.33	0.16
	S.e	0.06	0.05	0.10	0.05
I. aquatica	Min	0.20	0.02	0.23	0.11
	Max	0.32	0.41	0.43	0.34
	Mean	0.28	0.31	0.33	0.23
	S.e	0.07	0.11	0.10	0.11
T. australis	Min	0.21	0.21	0.16	0.14
	Max	0.30	0.34	0.27	0.20
	Mean	0.25	0.28	0.22	0.17
	S.e	0.05	0.07	0.06	0.03
S. cubensis	Min	0.31	0.23	0.28	0.31
	Max	0.43	0.43	0.32	0.65
	Mean	0.36	0.33	0.31	0.54
	S.e	0.06	0.10	0.02	0.19

Table 4. Mineral composition in plant samples from Kpong

Aquatic plants		Na (mg/L)	Ca (mg/L)	K (mg/L)	P (mg/L)
N. lotus	Min	0.01	0.27	0.19	0.03
	Max	0.16	0.41	0.43	0.11
	Mean	0.10	0.35	0.28	0.08
	S.e	0.08	0.07	0.13	0.04
I. aquatica	Min	0.16	0.41	0.42	0.05
	Max	0.23	0.56	0.51	0.16
	Mean	0.20	0.46	0.45	0.11
	S.e	0.04	0.08	0.05	0.05
T. australis	Min	0.10	0.32	0.34	0.05
	Max	0.23	0.56	0.52	0.16
	Mean	0.15	0.45	0.42	0.11
	S.e	0.07	0.12	0.09	0.05
S. cubensis	Min	0.23	0.46	0.12	0.54
	Max	0.43	0.65	0.32	0.67
	Mean	0.33	0.55	0.21	0.62
	S.e	0.10	0.09	0.10	0.07

Table 5. The concentration of heavy metal in plant samples from Ada

Aquatic plants		Cu (mg/L)	As (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)
N. lotus	Min	2.34	0.01	1.65	0.07	0.57	0.08
	Max	3.45	0.18	2.0	0.16	0.75	0.12
	Mean	2.71	0.08	1.8	0.12	0.66	0.10
	S.e	0.64	0.08	0.17	0.05	0.09	0.02
I. aquatica	Min	0.45	0.02	0.13	0.14	0.23	0.01
	Max	0.57	0.19	0.23	0.17	0.24	0.06
	Mean	0.52	0.12	0.18	0.15	0.23	0.03
	S.e	0.06	0.08	0.05	0.02	0.00	0.02
T. australis	Min	0.34	0.23	0.20	0.13	0.18	0.08
	Max	0.43	0.28	0.32	0.32	0.23	0.15
	Mean	0.39	0.25	0.27	0.23	0.21	0.12
	S.e	0.05	0.03	0.06	0.10	0.03	0.04
S. cubensis	Min	0.23	0.01	0.05	0.36	0.25	0.06
	Max	0.25	0.23	0.19	0.52	0.37	0.21
	Mean	0.24	0.14	0.11	0.44	0.32	0.15
	S.e	0.01	0.11	0.07	0.08	0.06	0.08

Table 6. Compositions of heavy metal in plant samples from Kpong

Aquatic plants		Cu (mg/L)	As (mg/L)	Zn (mg/L)	Cd (mg/L)	Pb (mg/L)	Cr (mg/L)
N. lotus		2.61	0.01	0.72	0.08	0.67	0.01
	Max	6.41	0.06	2.81	0.15	0.97	0.23
	Mean	4.07	0.03	1.91	0.12	0.80	0.14
	S.e	2.04	0.02	1.10	0.04	0.15	0.11
I. aquatica	Min	0.26	0.06	0.06	0.10	0.23	0.07
	Max	0.43	0.20	0.21	0.13	0.30	0.16
	Mean	0.34	0.13	0.15	0.11	0.25	0.12
	S.e	0.09	0.02	0.08	0.01	0.04	0.05
T. australis	Min	0.17	0.14	0.26	0.13	0.17	0.13
	Max	0.63	0.20	0.42	0.23	0.23	0.32
	Mean	0.44	0.18	0.36	0.19	0.20	0.23
	S.e	0.24	0.03	0.09	0.05	0.03	0.10
S. cubensis	Min	0.08	0.16	0.25	0.32	0.25	0.02
	Max	0.12	0.34	0.63	0.47	0.38	0.19
	Mean	0.10	0.23	0.40	0.38	0.32	0.12
	S.e	0.02	0.09	0.20	0.08	0.06	0.08

Table 7. Physicochemical parameters of water samples from Ada, Kpong, and Amedeka

Parameter		Ada	Kpong	Amedeka (Control)
pH	Min	6.4	6.20	6.5
	Max	7.0	6.53	6.9
	Mean	6.5	6.37	6.67
	S.e	0.1	0.16	0.15
	Min	28.40	30.10	29.2
Temperature (°C)	Max	30.20	32.60	32.3
	Mean	29.17	31.73	30.93
	S.e	0.93	1.42	0.68
	Min	2	13	2
Turbidity (NTU)	Max	17	17	3
	Mean	5.40	14.67	2.33
	S.e	1.28	2.08	0.58
	Min	17.6	8.6	22.3
DO (mg/L)	Max	19.2	12.7	26.6
	Mean	18.43	10.77	24.42
	S.e	0.80	2.06	2.50
	Min	6.5	1.6	0.93
BOD (mg/L)	Max	8.4	4.5	1.87
	Mean	7.57	3.10	1.13
	S.e	0.97	1.45	0.21
	Min	1.25	2.2	0.76
Nitrate (mg/L)	Max	1.84	2.4	1.23
	Mean	1.47	2.30	0.97
	S.e	0.32	0.10	0.01
	Min	0.43	0.71	0.53
Phosphate (mg/L)	Max	0.71	0.92	0.87
	Mean	0.55	0.81	0.73
	S.e	0.14	0.11	0.11
Sulphate (mg/L)	Min	4.0	5.0	4.12
	Max	4.0	6.0	4.67
	Mean	4.0	5.33	4.33
	S.e	0.00	0.14	1.53

Ether extract

The average percentage of ether extract of the plant samples from Ada fell from 6.3% in *S. cubensis* to 9.9% in *I. aquatica*. ANOVA at a 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*.

However, the average percentage of ether extract in the plant sample from Kpong ranged from 5.5% in *S. cubensis* to 12.4% in *I. aquatica*. ANOVA at a 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 a 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 a 95% family-wise confidence level suggested that the ash content in the sampled plants was statistically significant. However, the least significant difference showed no significant differences in the average between T. australis, S. cubensis, and I. aquatica. Still, 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 fiber

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 a 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 a 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 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 a 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 a 95% family-wise confidence level indicated that the NFE content in the sampled plants was highly statistically significant. The least significant difference revealed no substantial differences in the average of NFE between *T. australis* and *S. cubensis* but was yet different from *N. lotus* and *I. aquatica*. The average percentage NFE content in the studied plants in decreasing order of value are as follows; *S. cubensis* > *T. australis* > *N. lotus* > *I. aquatic*.

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 a 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 a 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 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 the 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 while 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 the 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 taken 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 the Ada sampling location fell from 0.23-0.43 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 the 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 while 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 six selected heavy metals were detected in the plant samples at the Ada 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 the 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. australis,* and *S. cubensis* respectively while 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. australis,* and *S. cubensis,* respectively.

The arsenic concentration in plants sampled at the 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. australis, and S. cubensis* respectively while 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. australis,* and *S. cubensis* respectively.

The zinc concentration in plants sampled at the 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.australiss, and S. cubensis* respectively, while 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. australis,* and *S. cubensis* respectively.

The Cadmium concentration in plants sampled at the 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. australis, and S. cubensis* respectively while 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. australis,* and *S. cubensis* respectively.

The lead concentration in plants sampled at the 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. australis, and S. cubensis* respectively while 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. australis,* and *S. cubensis* respectively.

Physicochemical parameters of water

Temperature and pH

The water temperature sampled at the Ada stretch of the river ranged from 28.4 to 30.2ºC with an average value of 29±0.9ºC, and that of the Kpong stretch of the river varied from 30.1-32.6ºC with an average temperature of 31.7±1.0ºC. At the same time, that of Amedeka fell from 29.2-32.3ºC with a mean temperature of 30.93± 0.68ºC.

Statistical analysis using ANOVA displayed that there were statistically no significant differences in temperature between the three sampling locations ($t=42.2$, $P<0.05$) at a 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 the 0.854. There was, however, a weak correlation between temperature and the following metals Zn, Cu, Cr, and As.

The water pH sampled at the 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 Amedeka range from 6.3 to 6.9 with a pH of 6.70±0.15.

Statistical analysis using ANOVA indicates no significant difference in the pH average 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% levels 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 an average of 10.7±2.0 mg/L, and that of Amedeka ranged from 22.3 mg/L to 26.6 mg/L with a mean DO value of 24.40±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 7.5.4±0.9 mg/L, and 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 Amedeka 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 no statistically significant differences in dissolved oxygen between the water at Kpong and Amedeka. There was, however, a statistically significant difference in dissolved oxygen content between (Kpong and Amedeka) and (Amedeka 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, sulphate, and phosphate

The nitrate level of the water sampled at the 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, and 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 Amedeka ranged from 0.76 mg/L to 1.23 mg/L. ANOVA revealed no statistical difference between water from Amedeka and Ada sampling locations, but a significant difference was shown between (Amedeka and Kpong) and (Ada and Kpong) sampling locations ($P<0.05$).

The sulfate concentration of the water sampled at the 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 5.3±0.5 mg/L, and that from Amedeka fell from 4.12 mg/L to 4.67 mg/L with an average 4.33 mg/L. There

was, however, no statistically significant differences in sulfate levels between the three-sampling area (P>0.05).

The Phosphate level of the water sampled at the Ada stretch of the river ranged from 0.43 mg/L to 0.71 mg/L with an average reading of 0.5±0.1 mg/L; that of Kpong fell from 0.71-0.92 mg/L with an average value of 0.8±0.1 mg/L and that of Amedeka ranged from 0.53 mg/L to 0.87 mg/L with a mean value of 0.73±0.11 mg/L.

There were no statistically significant differences in phosphate levels between the three sampling locations using ANOVA (P<0.05).

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 0.1-0.6 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.

Correlation between Physico-chemical parameters and heavy metals in sediments

Considerable numbers of significant positive and adverse correlations were observed between the following physicochemical variables and heavy metals levels 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 levels in the lower Volta basin sediments.

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

Site	Cd	As	Pb	Cr	Zn	Cd
Ada	2.3±1.2	1.2± 0.3	0.47±0.02	1.4±0.25	7.5 ± 0.86	2.3 ± 1.2
Kpong	1.8±0.8	0.3±0.02	0.4±0.03	0.7 ±0.02 5	80 ± 0.8	1.8±0.8
Amedaka	0.8±0.02	0.1±0.01	0.2±0.001	0.4±0.001	2.3±0.02	1.2±0.03

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

Site	Sample	Parameter	Cd	As	Pb	Cr	Zn	Cd
Ada	Water	F	7.5	24.1	244.5	51.4	118.7	7.5
	Sediment	P-value	0.00*	0.00*	0.00*	0.00*	0.00*	0.10ns
Kpong	Water	F	8.5	32.3	185.9	47.2	114.3	11.2
	Sediment	P-value	0.00*	0.00*	0.00*	0.00*	0.00*	0.30ns
Amedak	Water	F	7.2	25.8	175.3	49.5	117.5	9.6
	Sediment	P-value	0.00*	0.00*	0.00*	0.00*	0.00*	0.20ns

P<0.05 probability level; ns: Not significant

Table 9. Pearson's product-moment Correlation between Physico-chemical parameters and heavy metals in sediments

VAR	pH	Temp	Cu	AS	Pb	Cr	Zn	Cd
pH	1					-0.543*		
Temp		1	-0.558	-0.503	).58	-0.5438	-0.722*	-0.960*
Cu			1		-0.692*			
As				1		).935**	).719*	
Pb					1			-0.632*
Cr						1		
Zn							1	).662*
Cd								1

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

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

Phytochemicals	*Nymphaea lotus*	*Ipomoea aquatica*	*Typha australis*	*Scirpus cubensis*
Alkaloids	+	-	+	+
Flavonoids	+	+	+	+
Saponins	+	+	+	+
Sterols	+	+	+	-
Phenols	+	+	+	+
Proteins	+	-	+	+
Terpenoids	+	+	-	+

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 four plant 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 in the study area's chosen communities, Kpong (50%) and Ada (50%). Concerning the sex of the individuals, 71 individuals were males, while 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 respondents engage in fishing while 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 while 53% were settlers. The educational degree of the respondents was sought, and it demonstrated that 39.2% of the community had a JSS education. In comparison, 15% had secondary/6th form education, Ten percent (10%) had a tertiary education with 1.7% having vocational, and 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% answered in the affirmative, while the rest said they don't use the plants to feed animals.

Similarly, 67.5% of the individuals attest that the plants harvested imposed medicinal value, while the remaining respondents thought the opposite. When the respondents' perspectives 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 water use for their various activities.

When the respondents were questioned whether they fish in regions densely populated with weeds, 32.7% answered in the affirmative, while 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 the majority representing 79.2%, answered in the affirmative.

On the possible water utilization for drinking purposes, 43.3% of the individuals drink the water directly from the river. In contrast, the remaining 56.7% use other sources, such as wells and boreholes, as significant 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 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, while source 45.8% said it had not raised the cost of shipping. The respondents noted that the vector-borne disease currently prevalent in the area is malaria instead of Schistosomiasis, which was the most 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 about which kind of livestock they have in their communities, 100% indicated the presence of cattle, goats, 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 that *N. lotus* has the highest 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 higher than a fresh early bloom *Panicum maximum* from Tanzania. Higher protein content makes it appropriate for animal feed and 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 Alfalfa hay (C.P= 16.91%, NFE= 40.55%) (Banerjee and Matai 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 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 Matai 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* was 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 animal 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 in *S. cubensis*.

The variation in 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 a relatively higher content of Copper and Zinc in *N. lotus* makes it more considerable to be incorporated into 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 as feed for animals and their overgrowth as weeds. The presence of secondary metabolites indicates that the plants are potential sources of pharmaceutical agents. This is because secondary metabolite derived from the plant has been shown to possess pharmacological activities and 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 temperature differences could be attributed to solar radiation, which relies on weather conditions and water mixing. However, the water temperature at the three sampling locations was higher than WHO's standard for drinking water. The time difference during sampling also accounts for temperature changes. Temperature serves an important role in governing the seasonal succession of the biota (Dhanalakshmi et al., 2013). Ofori-Danson and Ntow (2005) made a similar observation in the Volta River.

The lower pH values at Ada and Kpong may be due to the number of plants whose photosynthetic activities released carbon dioxide into the water, forming carbonic acid and reducing the pH. The pH that ranged between 5.0 and 9.0 at the sampling locations was considered appropriate for aquatic plant growth and fish survival (Jobbling 1995). Values of pH outside the range of 5.0 to 9 should be regarded as indications of industrial pollution or some cataclysmic event. Nevertheless, the pH of the water sampled at three sites all fell within the standard of WHO guidelines of drinking water.

The low DO record at Ada and Kpong reflects the high number of living organisms in the plant in the water. The aquatic plants impeded the water flow rate within infested areas on the field. 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 water body is much oxygenated despite the presence of numerous aquatic plants.

BOD values measured for Ada and Kpong were higher than the control location'. 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 the two locations above fell within the scope of a moderately polluted water body. Thus, it implies that aquatic plants exert some pollution level on the 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. 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 those at the control location. Nutrient levels were usually low in the water body 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 a result of runoff from fertilized farmlands and domestic waste. This partly accounts for the high nitrate levels in infested areas of aquatic plants. The nitrate levels of the water at the three sampling areas were, however, fell within the WHO guideline of nitrate in drinking water (10 mg/L).

The average sulfate concentration in freshwater bodies is 4.8 mg/L (Meybeck and Helmer 1989). The 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 sulfate level in the water could be due to the natural occurrence as sulfur occurs naturally in its reduced form in igneous and sedimentary rocks (Singleton 2000). However, the sulfate concentration at the three sampling points was 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 Mironga et al. (2012) in Lake Naivasha, that phosphate concentration in infested areas is lower than in uninfested areas. The natural background reading of phosphate (P-PO43-) in inland waters usually ranges from 0.005 to 0.05 mg/L (Dunne and Leopold 1978); the mean PO43-contents at all three sampling sites were outside the range. As witnessed during the study, the result might be attributed to washing utensils, clothing and bathing children and adults in the river at each sampling area.

The turbidity values of the water taken at Kpong and Ada were higher than that of Amedeka, which served as the control site. The average turbidity of Ada and Amedeka is similar; however, significant differences appear in the turbidity between Amedeka and Kpong on the one hand

and Ada and Kpon on the other side. The relatively high turbidity measured at Ada and Kpong may be due to the high levels of suspended particles originating from debris from the numerous aquatic plants.

All the heavy metal concentrations analyzed in the water were lower than the WHO guideline for drinking water except for cadmium and lead. The relatively high cadmium concentration in the study area might be coming from runoff from farms that use phosphate fertilizers containing cadmium (De Meeus et al. 2002). The lead amount exceeded the WHO guideline of lead in drinking water at Ada and Kpong. The primary sources of lead in the environment came from lead batteries and lead paints disposed of improperly (Rhue et al. 1992).

Except for cadmium, the differences in the concentrations of Chromium (Cr), copper (Cu), lead (Pb), Zinc (Zn), and Arsenic (As) in water and sediment samples at the sampling locations were significant. The corrosion of galvanized pipes on the canoes and other deposits, erosion of natural deposits, and runoffs from waste batteries and paints from the city and nearby surroundings could be the primary sources of heavy metal contamination in the water and sediments. The natural weathering of rocks beneath sediment might also be a potential source of heavy metal released into the deposits and the water column.

The social survey findings show that some community members often used some aquatic plants to feed animals such as cattle, pigs, goats, sheep, and poultry. Regular harvesting and feeding of animals with aquatic plants could lower the detrimental effects of these weeds on the water body. None of the respondents has ever employed any of the numerous aquatic plants as food. These findings contradict what Shah et al. (2010) reported in India: humans feed on aquatic. Again, 67% of the respondent indicated that the plants have medicinal value. This was confirmed by the results obtained in the phytochemical analysis.

Other socio-economic impacts of the aquatic plants suggest a loss of earnings opportunities as fishers could not access fishing and landing sites, as well as interference of the weeds with fishing gear and clogging of pumps. The abundance of aquatic plants has subsequently led to a reduction in fish catch.

Moreover, the aquatic weeds impede the flow rate of the water and provide excellent breeding grounds for mosquitoes. The phenomena were evident in the two communities, Kpong and Ada, as respondents indicated the presence of numerous mosquitoes at night. However, the respondent stated a decline in schistosomiasis, which previously was a significant water health-related issue in the communities.

Although 92.3% of the respondent attested to the vegetation harboring wild animals such as snakes, there has not been any incidence of snake bites in the communities from the river.

Conclusion

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 four plant species have higher nutritional value than *P. maximum*. The exploitation of these aquatic plants will not only be 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 aid in the management of aquatic plants within the LVB.

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

The physicochemical parameters of water (pH, nitrates, DO, BOD) revealed that most of the water parameters differed significantly from the control site. The concentrations of heavy metals in the waterfall are 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 sediment fraction.

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

REFFERENCE

Annang TY. 2008. Harvesting, Composting, and Utilization of Compost for Improved soil fertility and crop productivity. Volta Basin Research Project, University of Ghana, Legon.

Anon. 1984. Making aquatic weeds useful: some perspectives for developing countries. National Academy of Sciences, Washington, D.C.

Ansa-Asare OD, Asante AK. 1998. A comparative study of the nutrient status of two reservoirs in southeast Ghana. Lakes and reservoirs. Res Manag 3: 205-217.

Asante KA, Quarcoopome T, Amevenku FYK. 2008. Water Quality of the Weija Reservoir after 28 years of Impoundment. West Afr J Appl Ecol 13 (1): 125-131.

Banerjee A, Matai S. 1990. Composition of Indian aquatic plants in relation to utilization as animal forage. J Aquat Plants Manag 28: 69-73.

Barry B, Obuobie E, Andreini M, Andah W, Pluquet M. 2005. TheVolta river basin. Comparative study of river basin development and management. Rapport, IWMI, CAWMA.

de Graft Johnson K. 1996. Integrated control of aquatic weeds in Ghana. Strategies for Water Hyacinth Control. In: Charudattan R, Labrada R, Center TD, Kelley-Begazo C (eds.). Strategies for Water Hyacinth Control, Report of a Panel of Experts Meeting September 11-14, 1995, Fort Lauderdale, Florida, USA.

De Meeus C, Eduljee GH, Hutton M. 2002. Assessment and management of risks arising from exposure to cadmium in fertilisers. I. Sci Total Environ 291 (1): 167-187.

De Silva SS, Anderson TA. 1994. Fish Nutrition in Aquaculture (Vol. 1). Springer Science and Business Media, Berlin.

Dhanalakshmi V, Shanthi K, Remia K. 2013. Physicochemical study of Eutrophic pond in Pollachi town, Tamilnadu, India. Intl J Curr Microbiol Appl Sci 2 (2319-7706): 219-227.

Dunne T, Leopold LB. 1978. Chemical characteristics of water. In: Dunne T, Leopold LB (ed.) Water in Environmental Planning. W.H. Freeman and Company, New York.

El-Shinnawy IA, Abdel-Meguid M, Eldin MMN, Bakry MF. 2000. Impact of Aswan High Dam on the Aquatic Weed Ecosystem. ICEHM2000, Cairo University, Egypt.

Ghana Bulletin. 2013. EPA, VRA abandon US$830,000 harvesters?. Retrieved 23 July 2015, from http://ghanabulletin.com/epa-vra-abandon-us830000-harvesters/.

Gott B. 1999. Cumbungi, ipo species: A staple Aboriginal food in southern Australia. Austr Aboriginal Stud 1999 (1), 33.

Jobling M. 1995. Environmental Biology of Fishes. Chapman & Hall, London

Junk WJ, Piedade MTF. 1997. Plant life in the floodplain with special reference to herbaceous plants. In: The Central Amazon Floodplain. Springer, Berlin.

Kalita P, Mukhopadhyay PK, Mukherjee A.K. 2007. Food Chemistry Evaluation of the nutritional quality of four unexplored aquatic weeds from northeast India for the formulation of cost-effective fish feeds. Food Chem 103: 204-209.

Karikari A, Akabey F, Abban E. 2013. Assessment of water quality and primary productivity characteristics of Volta Lake in Ghana. Acad J Environ Sci 1 (5): 88-103.

Lata N, Dubey V. 2010. *Eichhornia crassipes* a suitable economic feed: the world's worst aquatic weed. J Food Technol 8 (3): 102-105.

Malik A. 2007. Environmental challenge Vis a Vis opportunity: the case of water hyacinth. Environ Intl 33 (1): 122-138.

Meybeck M, Helmer R. 1989. The quality of rivers: from pristine stage to global pollution. Glob Planet Ch 1 (4): 283-309.

Milner BA, Whiteside PJ. 1981. Introduction to Atomic Spectrophotometry. Pye Unicam Ltd., Cambridge, England.

Mironga JM, Mathooko JM, Onywere SM. 2012. Effect of water hyacinth infestation on the physicochemical characteristics of Lake Naivasha. Intl J Human Soc Sci 2 (7): 103-113.

Nordeide MB, Holm H, Oshuag A (1994). Nutrient composition and protein quality of wild gathered foods from Mali. Intl J Food Sci Nutr 45: 275-286.

Ofori-Danson PK, Ntow WJ. 2005. Studies on the current state of the limno-chemistry and potential fish yield of Lake Volta (Yeji sector) after three decades of impoundment. Ghana J Agric Sci 38: 65-72.

Ogle BM1, Dao HT, Mulokozi G, Hambraeus L. 2001. Micronutrient composition and nutritional importance of gathered vegetables in Vietnam. Intl J Food Sci Nutr 52 (6): 485-499.

Petosa AR, Jaisi DP, Quevedo IR, Elimelech M, Tufenkji N. 2010. Aggregation and deposition of engineered nanomaterials in aquatic environments: role of physicochemical interactions. Environ Sci Technol 44 (17): 6532-6549.

Prasad KN, Shivamurthy GR, Aradhya SM. 2008. *Scirpus aquatica*, an underutilized green leafy vegetable: a review. Intl J Bot 4 (1):123-129.

Rhue RD, Mansell RS, Ou LT, Cox R, Tang SR, Ouyang Y. 1992. The fate and behavior of lead alkyls in the environment: A review. Crit Rev Environ Sci Technol 22 (3-4): 169-193.

Shah KA, Sumbul S, Andrabi SA. 2010. A Study on Nutritional Potential of Aquatic Plants. Vet Scan 5 (1); article 53. http://www.vetscan.co.in/v5n1/study_on_nutritional_potential_of_aquatic_plants.htm

Singleton HJ. 2000. Ambient water quality guidelines for sulphate. Ministry of Environment, lands and Parks, Province of British Columbia, Victoria, BC, Canada.

Straskaba M, Tundisi JG. 1999. Guidelines of Lake Management, vol. 9. Reservoir Water Quality Management. Lake Environment Committee Foundation, Shiga, Japan

Thakre G, Shrivastava N, Mishra DD, Bajpai A. 2010. Limnological studies to assess the water quality of" tapti pond" at Multai District, Betul (M. P.). Intl J Chem Sci 8 (4): 2105-2114.

Wiersema JH. 1982. Distributional records for *Nymphaea lotus* (Nymphaeaceae) in the western hemisphere. SIDA, Contrib Bot 230-234.