Research Article

Composition of Water Hyacinth (*Eichhornia crassipes*) Plant Harvested from the Volta Lake in Ghana and its Potential Value as a Feed Ingredient in Rabbit Rations

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Abstract | The water hyacinth plant is an invasive aquatic weed which colonizes vast areas of water bodies; it minimizes fishing grounds and blocks water ways. This study was conducted to screen water hyacinth plants spreading on the Volta Lake in Ghana, and assess its potential as a feed ingredient in rabbit rations. Fresh plants were harvested prior to flowering and sectioned into leaves, leaf sheaths and roots, after which it was dried till constant weights were attained. The dried products were milled and stored in air-tight containers, and portions used for proximate, heavy metal and fatty acid profile analyses. The most abundant fatty acids in the plant were palmitic, Linoleic and Linolenic acids. Levels of heavy metals such as Copper, Zinc, Lead and Iron in various parts of the plant were lower than the maximum permissible levels for use by livestock and humans. The leaves and leaf sheaths had crude protein contents of 20 % and 10 % respectively, and average fibre content of about 20%. The plant however, had low levels of fat that could possibly reduce palatability and thus hinder voluntary intake by some livestock species. Consequently, the experimental diets had higher crude protein, crude fibre and lower fat contents as water hyacinth inclusion increased. There was no significant effect on growth rate as water hyacinth plant meal replaced wheat bran up to 10% inclusion, but growth rate reduced as WHM inclusions increased to 15% in rabbit rations; cost of feed reduced by up to GH₵ 9.00 ($1.60 USD) with replacement. Further studies should consider the carcass and meat qualities of rabbits fed water hyacinth meal diets.

Keywords | Aquatic weeds, Invasive plant species, Heavy metals, Water hyacinth, Fatty acid profile

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INTRODUCTION

Water hyacinth (*Eichhornia crassipes*), belonging to the family Pontederiaceae, is a prominent fresh water plant found throughout tropical and sub-tropical regions of the world. It presents as a floating biomass, with long round spongy stems and leaves (Reza and Khan, 1981). The plant forms large floating mats which cover the entire water surface within a short period. When allowed to propagate, it quickly colonizes the water mass causing detrimental effects, including loss of fishing grounds, occlusion of water ways for navigation, interference with hydroelectric power generating plants, and providing a habitat for breeding of agents of malaria and bilharzia, as well as suppression of other useful aquatic life (Mathur, 2007; Jayan and Sathyanathan, 2012). The plant reproduces by means of runners or stolons, which eventually form daughter plants; and when this decay, the process leads to depletion of dissolved oxygen in the water, often killing fish and other aquatic organisms (Coles and Kabatereine, 2008). Several means such as spraying with herbicides, and occasional desilting of the water bodies in which they grow have been tried to control its rapid growth and spread, but these have not yielded any meaningful result due to its varied adaptive strategies for survival (Bindu and Ramasamy, 2005).

In Ghana, water hyacinth has invaded and is rapidly spreading within water bodies such as the Volta lake (personal communication). The current control measure locally for this plant is the use of chemicals which result in water pollution and destruction of some useful aquatic species. Studies by Bagnal et al. (1974) and Shiralipour and Smith (1984) indicate that water hyacinth could possibly be regarded as a useful resource, with a wide range of applications in China, India and Vietnam. It was suggested that these other means of utilizing the water hyacinth plant, for example in its use as manure, fibre, and as animal feed, could aid in its control (Jafari, 2010).

Earlier studies (El-Serafy et al., 1981; Igbinosun and Amako, 1988) also reported the potential of water hyacinth meal in formulating feed for fish. In Ghana and other African countries, feed for commercial production accounts for over 50% of the total cost of rearing livestock under intensive system of production. This is mainly due to competition between humans and livestock for the same staples, mainly cereals and fish (Madubuike and Ekenyem, 2001; Yilmaz et al., 2005; Teye et al., 2020). Consequently, animal nutritionists are stepping up efforts at screening non-conventional, less expensive but wholesome plant materials, for use in compounding nutritious diets for livestock (Ray, 1995; Cruz-Velásquez, 2014; Agbolosu et al. 2014; Nuamah et al. 2019; Teye et al., 2020).

Earlier studies reported that water hyacinth has appreciable levels of crude protein (18%) with good digestibility in some livestock species (El-Serafi et al., 1981; Jana et al., 2015), although levels vary from location to location. There is inadequate information on the chemical and nutritional quality of water hyacinth plants growing in the Volta lake in Ghana. Water hyacinth meal has similar characteristics as wheat bran, in terms of density and nutrient content (Nuamah et al, 2019). In this study therefore, water hyacinth was used as a partial substitute for wheat bran (an important feed ingredient in poultry and pig diets in Ghana) in rabbit rations.

MATERIALS AND METHODS

Study area

This study was conducted at the Teaching and Research Farm of the School of Agriculture, University of Cape Coast, Ghana. The area experiences a bimodal rainfall regime with a mean annual rainfall of 920mm. Temperatures are relatively high with annual mean of 23 ^{0}C. The relative humidity is about 90 % in the night and decreases gradually to 70 % in the afternoon between May and September (Teye et al., 2020). The methodology involved in handling rabbits in this study was approved by the Department of Animal Science's Animal Welfare Committee, University of Cape Coast, Ghana.

Harvesting and processing of water hyacinth plants

Fresh water hyacinth plants were manually harvested prior to flowering from open waters of the Volta Lake, at Kpong, near Akosombo in the Eastern Region of Ghana. The harvested plants were washed with potable water and then sectioned into roots, leaf sheaths and leaves. Each section was spread evenly on clean polythene sheets under shade, to wilt at approximately 28^{0}C, for 5 days. The wilted plants were then packed into an electric oven (Genlab, CAPCO) to dry at a temperature range of 60 – 65^{0}C, until constant weights were attained. The dried plant parts were milled with a conventional hammer mill, and packed into transparent air-tight polyethene bags for later use.

Proximate Analyses of Water Hyacinth Plant Samples

The proximate composition of the roots, leaf sheaths and leaves of the plants were determined in the Nutrition laboratory of the School of Agriculture, University of Cape Coast. The crude protein, ether extract, dry matter and ash contents were determined according to the methods described by the Association of Official Analytical Chemists (AOAC, 2000). All analyses were conducted in triplicate.

Analyses for Presence of Heavy Metal in Water Hyacinth Plant Samples

The Iron, Copper, Cadmium, Lead and Zinc contents were determined using the Atomic Absorption Spectrophotometer (AAS). All analyses were conducted in triplicate.
The methods used by Akram et al. (2015) were followed, with few modifications. A known quantity (1g) of the dried water hyacinth plant meal samples were weighed into Erlenmeyer flasks, and moistened with 3.0 ml of water; 7.5 ml of concentrated hydrochloric acid was added successively, after which 2.5 ml of concentrated nitric acid was added in a fume chamber. The containers were each covered with a watch glass for 12 hours, and later refluxed for 2 hours. Samples were then cooled at ambient temperature. The extracts were filtered on an acid resistant filter into 100 ml volumetric flasks to obtain clear filtrates. The digestion vessels and the residue on the filter paper were rinsed with 2 M hot nitric acid (50 ^{0}C). The filtrates were allowed to cool, then diluted to 100 ml with 2 M nitric acid solution. The analyses for Fe, Cd, Pb and Zn were carried out using the atomic absorption spectrophotometer (AA 7000, Shimadzu, Japan). The operating conditions are indicated in Table 1.

Table 1: Operating Parameters for Atomic Absorption Spectrophotometer Analyses

Element	Wavelength (nm)	Slit width (nm)	HCl current (mA)	Flame
Fe	248.3	0.2	12	Air-acetylene
Cd	228.8	0.7	8	
Pb	283.3	0.7	10	
Zn	213.9	0.7	8	

Table 2: Ingredient Composition of the Experimental Diets (Kg)

Ingredients (Kg)	Control (0%WHM)	5%WHM	10% WHM	15% WHM
Maize	48	48	48	48
Wheat bran	35	33.25	31.5	29.75
Water Hyacinth meal	0	1.75	3.5	5.25
Fish meal	15	15	15	15
Oyster shells	1.45	1.45	1.45	1.45
Vitamin Premix	0.25	0.25	0.25	0.25
Common salt	0.3	0.3	0.3	0.3
Total	100	100	100	100
Calculated nutrient composition				
Crude protein	17.45	17.18	16.9	16.62
Ether extract	3.99	3.92	3.86	3.79
Crude fibre	4.97	4.8	4.63	4.46
Calcium	0.61	0.6	0.6	0.6
Phosphorus	0.5	0.48	0.46	0.44
Methionine	0.59	0.58	0.58	0.57
Lysine	1.47	1.46	1.45	1.44
ME(Kcal/kg)	2629.51	2600.81	2572.11	2543.41

Premix (0.25%) provided the following: Vit A 10.000 IU; Vit D3 2,000 IU; Vit E 15 mg; Vit K3 stab 1.5 mg; Vit B1 0.5 mg; Vit B2 2.5 mg; Vit B6 1.0 mg; Vit B12 6μg; Niacin 5 mg; Calpan 4 mg; Folic Acid 100 μg; manganese 60 mg; iron 40 mg; zinc 50 mg; copper 2.5 mg; iodine 1mg; Selenium 0.2 mg; choline 100 mg; antioxidant 125 mg.

All reagents were of analytical grade purity obtained from the Wako Pure Chemical Industries Ltd, Japan: Cd $(NO_3)_2$ $4H_2O$; Pd $(NO_3)_2$; Fe $(NO_3)_2$ and Zn $(NO_3)_2$, $4H_2O$. Stock solutions (100 – 1000ppm.) of each heavy element of interest were prepared; the required standards were prepared daily by appropriate dilution of the stock solution. To avoid contamination, glasswares were rinsed with concentrated nitric acid in a sub-boiling system, then again with deionized water, before use. Water was purified with a double-distilled deionization system. All dilutions and standard solutions were prepared in this deionized water.

Fatty Acid Profile Determination in Water Hyacinth Plant

The extraction of oil from the water hyacinth plant was performed at the Nutrition laboratory of the School of Agriculture, whilst the GC–MS analyses of extracted fats were performed at the Central laboratory of the Department of Chemistry, all in the University of Cape Coast, Ghana. The water hyacinth plant samples were subjected to Soxhlet extraction with petroleum ether (40-60) for 8 hours (AOAC, 2000). The extract was evaporated to leave behind a pale-yellow oil. The oil was trans-esterified using methanol to form fatty acid methyl esters (FAMEs) using the methods described by Opoku-Boahen and Barku (2007). The FAME was collected in hexane and subjected to GC–MS (QP 2020, Shimadzu) equipped, with an RTx 5 MS column (30 m x 0.25 mm i.d x 0.25 μm film thickness) to identify the fatty acid composition of the plant.

Experimental Feeds and Feeding

Based on findings from the proximate and heavy metal analyses (relatively lower nutrient but higher heavy metal contents), the root meals were discarded, but the leaf sheaths and leaf meals were mixed to form the water hyacinth meal (WHM) which was used to partially replace wheat bran in rabbit rations. Four experimental diets were formulated using the Windows User-Friendly Feed Formulation Excel file (Thomson et al., 2009). Water hyacinth meal (WHM) replaced wheat bran at 0% (Control), 5%, 10% and 15% (Table 2). The feeding trial lasted for 42 days, during which feed and water were provided to the animals *ad-libitum*. All diets were formulated to meet the requirements for essential nutrients for growing rabbits as recommended by the National Research Council (NRC, 1994). The composition of the experimental diets is shown in Table 2.

Prior to the start of the feeding trial, the rabbits were placed on the experimental feeds for 10 days to acclimatize to the feed and research environments. The initial weights of rabbits were taken using an electronic scale (RADWAG 2012, RADWAG®). Subsequently, weekly body weights of animals were also taken. The weekly weight gained was calculated as the difference between previous weight and the current weekly weight. Given quantities of feed were offered to the animals daily and leftovers/spilled feed weighed after 24 hours, before new feed was provided. Feed intake per rabbit per day was calculated as the difference between feed offered and that spilled/leftover, after 24h. Feed conversion ratio (FCR) was calculated as the ratio of feed consumed to weight gained after each week of feeding, according to the formula of Nuamah et al. (2019).

Analyses of Experimental Data

Data were analysed using the Analysis of Variance (ANOVA) component of the Minitab Statistical Package (Minitab® Inc. version 17). Where significant differences were found, the means were separated using the Tukey pair-wise comparison, at 5% level of significance.

RESULTS AND DISCUSSION

The proximate composition of the dried water hyacinth plants is presented in Table 3.

The dry matter and crude fibre contents of the leaf sheaths were higher ($p < 0.001$) than in the leaves and roots of the plant. The fibre content in the various parts of the plant was generally higher than that of most conventional feed ingredients used for producing feed for non-ruminant livestock species. This implies that WHM may not be suitable for use as feed ingredient for non-ruminant livestock species, but will likely better suit ruminant and pseudo-ruminant species like rabbits (Pond et al., 1995). The crude protein and ether extract contents were higher ($p<0.001$) in the leaves than in other parts of the plant; the roots had higher ($p<0.001$) ash content than the other parts of the plant. The leaves of water hyacinth plants have been reported by Abdelhamid and Gabr (1991) to have generally higher levels of nutrients than the shoots and roots. Consequently, feeding trials are conducted using either the leaves only, or leaves and leaf-sheaths, but not the roots of the plant. The crude protein content of up to 20% in the leaves, and about 10% in the leaf-sheaths (averaging 15% in water hyacinth meal) is comparable to those of feed ingredients such as wheat bran, commonly used in formulating feed for many classes of livestock in Ghana and around the world. Abdelhamid and Gabr (1991), reported crude protein level of 20% in the leaves of water hyacinth plants. According to Le Thi Men et al. (2006), the protein content in water hyacinth plants decreases as the plant ages. Mako et al. (2011) also indicated that the nutrient composition of water hyacinth plant varies with the nutrient content of the water in which the plant grew; thus wide variations in protein content of water hyacinth reported might be due to either the age of the plant or the level of pollution of the water from which it was harvested. The crude protein level in the leaves and leaf sheaths (WHM), is comparable with other feed ingredients such as wheat bran, palm kernel oil residue (PKOR) and mango seed kernel meal (MSKM) used widely in formulating livestock feed in Ghana (Odoi et al., 2007; Nuamah et al., 2019; Teye et al., 2020). These characteristics of the water hyacinth plant indicates that it has potential for use as feed ingredient in rations for livestock. The fat content in all parts of the plant however, was generally low. This might reduce its potential energy value, palatability and likely also reduce voluntary intake by animals (Pond et al., 1995).

The roots of the plants were generally poor in most of the nutrients determined. Coupled with the relatively higher concentrations of heavy metals, the roots appear unappealing for use as livestock feed. Therefore, only the leaves and leaf sheaths were bulked and named water hyacinth meal (WHM), which was used to formulate the experimental diets.

The heavy metals detected and their levels in various parts of the water hyacinth from the Volta Lake, are presented in Table 4.

The Copper, Zinc and Lead levels in the roots were significantly higher than those found in leaves and leaf sheaths. This observation might be due to the roles played by plant roots in nutrient absorption. In the process, some toxins and heavy metals are absorbed and trapped in the roots, hence, the higher levels in the roots compared with other plant parts. This observation is also in line with that of Matindi et al. (2014) who observed higher levels of iron and other heavy metals in the roots compared with leaves of water hyacinth plants harvested, from Lake Victoria in Kenya. In this study, though the levels of the mentioned heavy metals were higher in the roots than in other parts of the plants, these were generally lower than the maximum permissible limits of 1-2, 0.60 and 2 mg/kg for Copper, Zinc and Lead respectively for humans and livestock (WHO, 1996). High heavy metal concentrations in plants are often reported in soil and water bodies which are heavily polluted (Matindi et al., 2014; Ogundele et al., 2015).

Table 3: Proximate Composition (%) of dried Water Hyacinth leaves, leaf sheaths and roots

Parameter (%)	Leaves	Leaf sheath	Roots	P-value
Dry Matter (Fresh weight basis)	6.37 ± 0.02[c]	7.59 ± 0.03[b]	11.94 ± 0.05[a]	<0.001
Dry Matter (Dried form)	91.31± 0.23[b]	92.64± 0.04[a]	89.83± 0.11[c]	<0.001
Crude Protein	20.13± 0.19[a]	10.61 ± 0.48[b]	9.60± 0.12[c]	<0.001
Crude Fibre	18.61± 0.14[b]	22.92 ± 0.54[a]	19.08 ± 0.40[b]	<0.001
Ash	15.60± 0.20[c]	19.78± 0.22[b]	20.95± 0.27[a]	<0.001
Ether Extract	1.05± 0.02[a]	0.27± 0.01[b]	0.18± 0.01[c]	<0.001

Means in a row with common letter superscripts are not significantly different ($p > 0.05$).

Table 4: Levels of Heavy Metals Detected in Water Hyacinth Plants from the Volta Lake

Parameter (mg/kg)	Leaves	Leaf sheaths	Roots	P-value	MPL mg/kg
Copper	0.96 ± 0.02[c]	1.63 ± 0.73[b]	1.18 ± 0.06[a]	0.000	10
Cadmium	ND	ND	ND	-	0.02
Zinc	0.06 ± 0.03[b]	0.07 ± 0.01[b]	0.32 ± 0.04[a]	0.000	0.60
Iron	1.32 ± 0.09[b]	0.94 ± 0.03[b]	5.35 ± 0.4[a]	0.000	0.012
Lead	0.057 ± 0.16[b]	0.34 ± 0.10[ab]	0.66 ± 0.36[a]	0.059	2

Detection limits; Cd: 0.003 mg/kg, Zn: 0.002 mg/kg, Fe: 0.03 mg/kg, Cu: 0.078 mg/kg, Pb: 0.25 mg/kg. ND: Not detected (below detection limit), MPL: maximum permissible limit (WHO, 1996); Means in a row with common letter superscripts are not significantly different ($p > 0.05$).

The findings from this study implies that possibly the River Volta is relatively less polluted presently than the Lake Victoria in Kenya. However, there is need to monitor the levels with time, as pollution of the Volta River is increasing with more intensive fish culture activities. The relatively low levels of these heavy metals in plants used in the current study indicates that when such plants are fed to livestock, there would be minimal likelihood of encountering challenges associated with heavy metal toxicity. However, erring on the side of caution, use of the roots of the water hyacinth plants was decided against in livestock feed preparation for this study.

The fatty acid profile of the water hyacinth meal was determined to further assess its suitability for use as feed ingredient for livestock, and the result is presented in Table 5.

Table 5: Fatty Acid Profile of the Experimental Water Hyacinth Meal

Fatty acid	Concentration (%)
Suberic acid C6:0 $(COOH)_2$	0.30 ± 0.02
Myristic acid (C14:0)	1.34 ± 0.23
Palmitic acid (C16:0)	16.59 ± 2.44
Margaric acid (C17:0)	3.24 ± 0.18
Petroselinic acid (C18:1) ω-12	3.25 ± 0.21
Linoleic acid (C18:2) ω-6	5.28 ± 0.35
Linolenic acid (C18:3) ω-3	7.34 ± 1.02

Palmitic acid was the predominant saturated fatty acid detected in the water hyacinth plant from this study. This observation is in line with findings of Liebezeit et al. (2017), who reported significantly higher levels of C16:0, compared to C18:1 and C18:2 in water hyacinth plants from the Siak River system in Eastern Sumatra. Other saturated fatty acids identified were Suberic, Myristic and Magaric acids. This study recorded significant levels of two of the three major C18 unsaturated fatty acids (UFAs) often found in most plants (He et al., 2020), namely Linolenic acid (C18:3) and Linoleic acid (C18:2), which are essential fatty acids in monogastric nutrition. The third major C18 unsaturated fatty acid, Oleic acid (C18:1) however, was not identified in this study, although its isomer, Petroselinic acid (C18:1), was isolated. Other studies by Sanseverino et al. (2012) and Arayana et al. (1984) also reported similar fatty acid composition in water hyacinth plants from locations outside Africa.

Suberic acid is a dicarboxylic acid, and its presence in the water hyacinth plant is good news to animal nutritionists. This is because dicarboxylic acids in general provide a good source of energy, aid in control of micro-biological contaminants in feeds, acidify the feed to enhance growth performance, and improve animal health. In addition, these acids aid in the control of undesirable micro-organisms in the intestinal tract (Kempen, 1999). The high levels of palmitic acid in the water hyacinth plants however, may be a cause for worry, because being a saturated fatty acid, its availability in the plant might indirectly influence the fatty acid profile of meat from animals which feed on it.

The proximate composition of the experimental diets is presented in Table 6.

Table 6: Proximate Composition of Experimental Feeds

Parameter	Water Hyacinth Meal (WHM) substitution for Wheat Bran				P-value
	0 %	**5 %**	**10 %**	**15 %**	
Dry matter	86.45 ± 0.25[c]	87.50± 0.08[a]	87.41± 0.15[ab]	86.98±0.16[b]	<0.001
Ash	5.67 ± 0.20	5.77 ± 0.43	5.43 ± 0.19	5.44 ± 0.31	0.458
Crude Protein	15.90 ± 0.10[c]	15.25 ± 0.27[d]	18.49 ± 0.27[b]	19.14 ± 0.072[a]	<0.001
Crude Fibre	6.48 ± 0.33[d]	7.85 ± 0.22[c]	8.42 ± 0.35[b]	9.74 ± 0.15[a]	0.001
Ether Extract	12.94 0.03[a]	11.64 ± 0.01[b]	11.52 ± 0.11[b]	10.86 ± 0.04[c]	<0.001
NFE	61.36 ± 0.32	62.24 ± 0.49	62.04 ± 0.35	60.94 ± 0.52	0.340

abc = Means in a row with common letter superscripts are not significantly different (p>0.05); NFE = Nitrogen-Free Extract {100 – (%moisture+%ash+%CP+%CF+%EE)}

Table 7: Growth Performance of Rabbits on Experimental Diets

Parameter	Water Hyacinth Meal (WHM) substitution for Wheat Bran				P-value
	0%	**5%**	**10%**	**15%**	
Initial weight (g)	742.00	739.00	738.00	743.40	0.132
Daily feed intake (g)	94.50[a]	97.31[a]	92.90[ab]	90.93[b]	0.003
Growth rate (g/day)	19.45[a]	19.62[a]	19.04[ab]	18.91[b]	0.024
Feed Conversion Ratio (FCR)	4.86	4.96	4.88	4.81	0.084
Mortality (%)	25	8	-	-	
Cost of 100kg Feed (GH₵*)	178.94	177.43	174.82	169.50	-

* $1 (USD) = 5.6 GH₵; abc = Means in a row with common letter superscripts are not significantly different (p>0.05)

The dry matter content of the experimental feeds increased from the control diet to the 5% WHM diets, then decreased thereafter to the 15% WHM diet. The crude protein content increased (p < 0.001) with increasing level of WHM in the diets. This is promising because high protein content in livestock rations generally promote better growth rates as well as enhance repair of worn out tissues in animals on such diets (Pond et al., 1995). The ether extract content decreased with increasing water hyacinth inclusion level. This observation might be due to the generally low levels of ether extract in the water hyacinth plant, resulting in low overall fat content of the diets. This trend in fat levels might have adverse effects on intake of WHM diets because fat is known to improve taste as well as energy value of feeds (Pond et al., 1995). Therefore, feeds with lower fat content generally result in lower acceptability and growth in animals fed on them.

The growth performance of animals fed on the experimental diets is presented in Table 7.

Feed intake in rabbits on diets with the highest WHM inclusion rate (15%), significantly reduced (p < 0.001); the feed intake was however similar (p > 0.05) among animals on the 0%, 5% and 10% WHM diets (Table 7). The observation with the 15% WHM diet might be due to its relatively lower fat content which possibly reduced its palatability, or due to the higher fibre content on such diets. The lower feed intake consequently had adverse effects on growth rates of rabbits on the 15% WHM diets.'

Mortality in rabbits reduced markedly with increasing WHM inclusion (Table 7). The dead animals from the study exhibited signs of diarrhoea and bloat, on post-mortem analyses. This observation might be due to the beneficial effect of the higher fibre content in the diets with higher WHM inclusions; this likely increased bowel movement, and minimized levels of gas produced through fermentation of the feed (Pond et al., 1995). This effect of WHM on the digestive tract is good news to local Ghanaian farmers who might not have ready access to forages for their rabbits, especially during the dry seasons of the year, and so have to rely solely on formulated cereal-based rations. Such farmers have commonly observed increased mortalities associated with bloat and diarrhoea (personal communication), possibly due to low fibre content of the diet.

The cost of formulating 100kg of the 4 experimental diets for rabbits reduced from GH₵ 178.94 (for Control diet) to GH₵ 169.50 (for diet with 15% WHM in place of wheat bran) in rabbit rations. This implies that farmers could save up to GH₵ 9.00 (USD 1.60) with the use of WHM as a partial replacement for wheat bran, for every 100kg feed formulated. In addition to this benefit, the use of WHM as feed ingredient in rabbit rations could serve as a natural and more environmentally friendly means of controlling the plant, in attempts to overcome some of the challenges associated with its invasive growth in water bodies, including the Volta Lake.

CONCLUSIONS AND RECOMMENDATIONS

Copper, Zinc, Lead and Iron levels measured in water hyacinth plants harvested from the Volta lake in Ghana were within the maximum permissible levels for livestock and human use. Cadmium (a very poisonous metal) on the other hand, was not detected in the current study. The leaves and leaf sheaths of water hyacinth plants from the Volta Lake had fairly high crude protein contents of 20% and 10% respectively, and thus could be utilised as a feed ingredient in formulating rabbit diets. The plant however has very low levels of fat, which could possibly reduce its energy value, and also hinder palatability and voluntary intake by some livestock species. The use of water hyacinth meal, up to 15 % in place of wheat bran, reduced the cost of formulating 100 kg feed. On the whole therefore, water hyacinth plant meal could be used as substitute for wheat bran in rabbit rations as an environmentally friendly way to minimize hazards associated with its wild growth in water bodies.

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AUTHORS CONTRIBUTION

Moses Teye, V.Y.A. Barku, Charles Kyereme and Fred N.A. Odoi designed the study, and together harvested and dried the water hyacinth plants. Odoi F.N.A was in charge of formulation of feed, Moses Teye and Charles Kyereme were in charge of feeding the animals and collecting data on feed intake, growth rates and costing of the study. Moses Teye analysed the research data and together with F.N.A. Odoi, drafted the manuscript. V.Y.A. Barku was in charge of the proximate, heavy metal and fatty acid profile analyses for the study. All authors contributed to finetuning and proofreading of the final manuscript.

CONFLICT OF INTEREST

The authors declare that they have no competing interests, so far as this study is concerned.

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