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A Nutritional Evaluation of Water Hyacinth [*Eichhornia Crassipes* (Martius) Solms-Laubach] Meal Diets Supplemented With Maxigrain® Enzyme for Growing Pullets

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ABSTRACT

An experiment to evaluate the nutritional value of water hyacinth meal (WHM) for pullets was conducted using two hundred and thirty four (234) 12-weeks-old growing pullets. They were randomly allotted to six dietary treatments with three replicates per treatment. Diet 1 contained 0 % WHM, with no Maxigrain® enzyme added; Diet 2 and Diet 3 contained 10 and 20 % WHM respectively, with no Maxigrain® enzyme added; Diet 4 contained 0 % WHM with Maxigrain® enzyme added while Diet 5 and Diet 6 contained 10 and 20 % WHM respectively, but with Maxigrain® enzyme added. The 2 x 3 factorial experiments lasted for six weeks, during which time the birds were fed the experimental diets *ad libitum*. At the end of the 17th week, a digestibility trial using the total collection method was carried out. Results show that feed intake was significantly ($p<0.05$) higher for birds fed the 10 % (2762.83 g) and 20 % (2750.83 g) WHM diets than for birds fed the 0 % (2601.02 g) WHM diets; but there were no significant ($p>0.05$) differences in feed intake between the birds fed the enzyme-supplemented diets and those without enzyme supplementation. Feed conversion ratio (FCR) was significantly lower ($p<0.05$) for birds fed the enzyme supplemented diets (5.76) than for birds fed diets without enzyme supplementation (6.56). Hence, WHM can be included up to 20 % in the diets of growing pullets (replacing 100 % wheat offal) with no detrimental effects on growth performance and nutrient digestibility.

Keywords: Water hyacinth meal, growing pullets, exogenous enzymes.

INTRODUCTION

Water hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubach, is a free floating aquatic weed species with broad leaves and beautiful, purple or lilac-blue, lily-like lavender flowers [1]. It first made its entry into the Nigerian waters via the Southwest coastal border town of Badagry around September, 1984 [2].

Today, more than three decades after its first appearance in Nigeria, it is regarded as the most invasive and troublesome aquatic weed species [3]; colonizing natural lakes, rivers, water courses, manmade impoundments, irrigation channels and dams [4]. It is regarded as a terror in many nations of the world including USA, China, Argentina, Brazil, India, Sri Lanka, Indonesia, Thailand, Philippines, Vietnam, Egypt, Sudan, Congo, Malawi, Kenya, Uganda, Rwanda, Burundi, South Africa, Tanzania, Zimbabwe and Australia (Plate 1). In Nigeria, it is found in 20 out of the 36 states, including the Federal Capital Territory (FCT). It is called "Blue Devil" or "Benghal Terror" in India, "Florida Devil" in South Africa, "German Weed" in Bangladesh and "Water Terror" by fishing communities in creeks and lagoons of South Western Nigeria [5]. It is estimated that annual recurrent costs associated with water hyacinth globally is over 100 million U.S. dollars [6]. In China alone, water hyacinth grows in 17 provinces and has become a bio-disaster in these provinces. It is estimated that each year, more than 100 million RMB Yuan (equivalent of 12 million US dollars) is spent on its control throughout China, yet the weed remains vigorous and continues to spread [7].

It has been a tropical issue of discussion as numerous national and international conferences focussing on its chemical, biological and integrated control, with little success; the obnoxious weed is re-establishing itself in old territories and spreading into new regions at an alarming speed. Perhaps, the solution to the water hyacinth problem lies in developing it from its present menace status into an asset of national and international value; by seeing the plant as an opportunity instead of a problem. According to [8], the real challenge in the water hyacinth saga is not how to get rid of this weed but how to benefit from it and turn it into a crop. It is a prolific weed such that 10 plants can multiply vegetatively to 600,000 plants and virtually carpets an acre (0.40 hectare or 4046m^2) of water in only 8 months [9]. Hence, the focus of this research is to determine how this weed, regarded as a terror in many nations of the world, can be turned into an asset rather than a liability that is presently is. and also specifically to discover the significant role it can play in the animal feed industry in Nigeria, especially in the feeding of pullets - as layer chickens have been proved to be a more profitable aspect of poultry production than the rearing of broiler birds since layer birds have been estimated to contribute 65-75 % of the total poultry population in Nigeria [10].

Plate 1: *Water Hyacinth plants in full bloom*

The problem of water hyacinth meal (WHM) utilization in the animal feed industry is its high fibre content (15-22 %). The fibre is made up of non-starch polysaccharides (NSPs) such as cellulose, hemicellulose, pectin and lignin. Added to that is the suspected presence of galactosides, phytates and other anti-nutritional factors (ANFs) such as lectins and tannins in water hyacinth meal, hence the need for the addition of exogenous enzymes for its proper utilization in livestock feeds. Addition of exogenous enzymes to fibrous feedstuffs have been known to help break down and release cell wall constituents present in the feedstuff before they reach the terminal end of the small intestine; hence improving nutrient digestibility in poultry birds. Also, enzymes increase growth rate, decrease viscosity of intestinal digesta resulting in more normal rate of passage, improved feed conversion and reduced sticky droppings [11]. Hence, the objective of this study was to determine the growth performance, nutrient digestibility and economy of feed conversion of growing pullets fed diets containing varying levels of WHM with or without Maxigrain® enzyme supplementation.

MATERIALS AND METHODS

Preparation of water hyacinth meal

This was carried out using the procedure of [12]. Whole plants of water hyacinth were collected from the River Niger in Lokoja, Kogi State. The green plants were harvested freshly from the water surface, manually, and sun-dried at the bank of the River Niger for about seven days until they were well dried. They were then packaged in polythene sacks and transported to the Animal Production Laboratory, Federal University of Technology, Minna for further processing. Collections of the water hyacinth plant were carried out at two different periods of the year; the first collection period was at the peak of the dry season, during the month of March, and the second was at the peak of the rainy season, during the month of September. On arrival at the Animal Production Laboratory, the sundried plants were subjected to thorough inspection, and foreign matters (river debris, leather wrappings and other extraneous materials) were removed. They were then oven dried at 80^0C for about 24 h to a moisture content of about 10 %. The dried plants were then milled at the School of Agriculture and Agricultural Technology Feedmill Unit using an attrition mill and sieved through a 2 mm sieve to obtain water hyacinth meal (WHM) which was then stored in large plastic containers with tight-fitting lids until needed for use. The flow chart for the production of WHM from fresh water hyacinth plant is shown in Figure 1 while the photograph of the WHM is shown in Plate 2.

Chemical analysis of water hyacinth meal

The proximate composition of the WHM was determined using the procedures of [13] while its mineral composition was determined using the procedures of [14]. Fibre composition was determined using the procedure of [15]. The anti-nutritional factors in WHM were determined as follows: the method of [16] was used for phytic acid determination; the method of [17] was used for the determination of tannin while oxalate and saponin contents were determined using the standard procedures of [18]. Hydrocyanic acid, alkaloids, flavonoids, resins, steroids and phenols were determined using the standard procedures of [18].

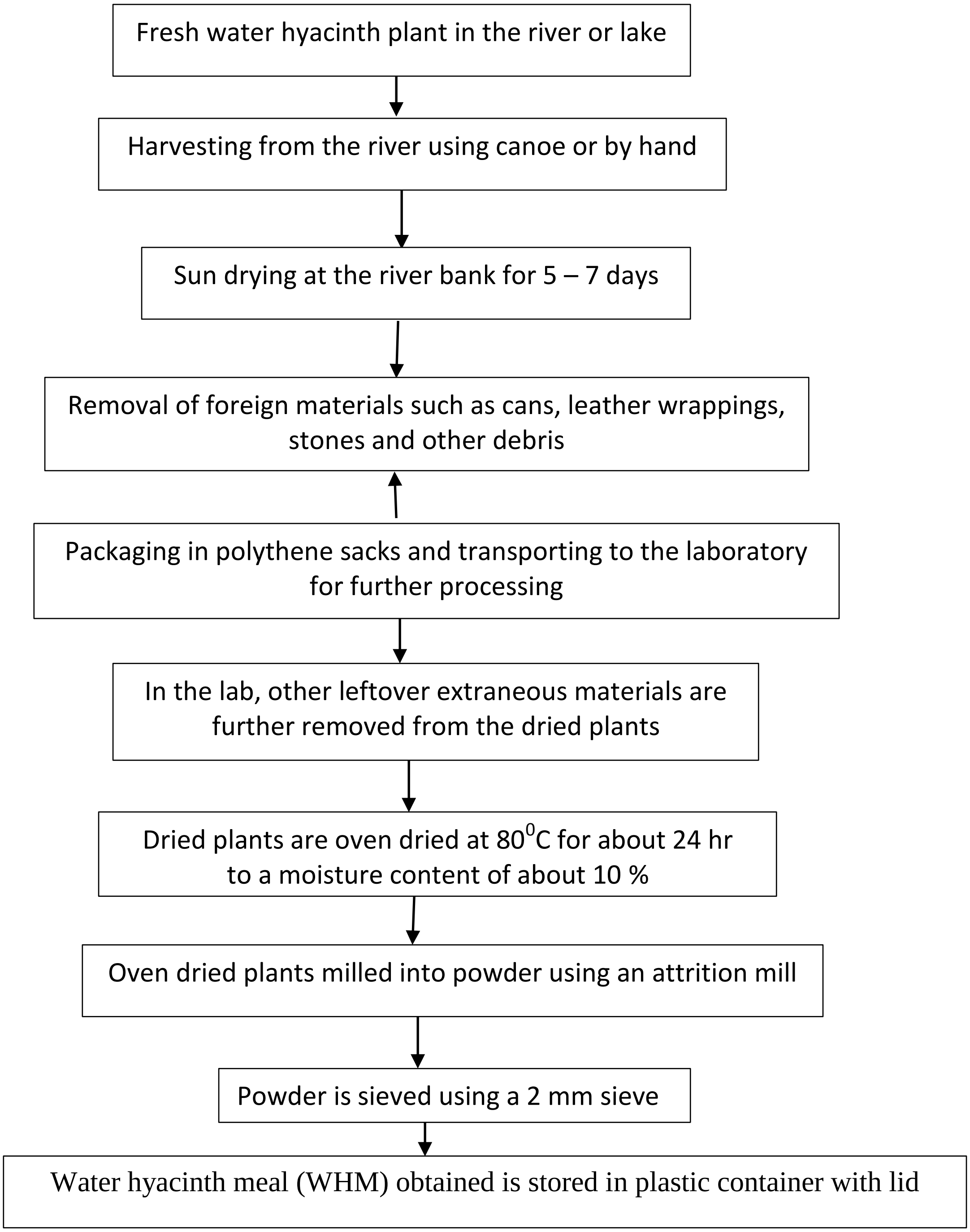

Fig. 1: Flow chart for the production of water hyacinth meal from fresh water hyacinth plant

Plate 2: Water hyacinth meal on paper and stored in a plastic container with lid

Experimental animals and diets

Two hundred and thirty four (234) 12-weeks'- old Isa Brown pullets were used for this study. They were raised from day-old at the Poultry Unit of the Animal Production Teaching and Research Farm, Federal University of Technology, Minna. The birds were randomly allocated to six dietary treatments of 13 birds per replicate and three replicates per treatment in a Completely Randomized Design experiment based on a 2 x 3 factorial arrangement. The treatments were made up of three levels of WHM (0 %, 10 % and 20 % dietary inclusion levels) and two levels of enzyme ("Without enzyme" and "With enzyme"). The exogenous enzymes used were a commercial grade enzyme named Maxigrain®. Each gramme of Maxigrain® contains 10, 000 IU cellulase, 200 IU β-glucanase, 10, 000 IU xylanase and 2, 500 FTU phytase. It was purchased at ANIMAL CARE, Kaduna, at the rate of ₦400 per sachet (100 g) and added at the rate of 100 g (a satchet) per 1000 kg of feed (i.e. 10 g per 100 kg of feed). It was added to each of the diets as a feed additive, after the composite ingredients have been thoroughly mixed together.

The experimental diets for the growing pullets were designated as follows: Diet 1 was the Control Diet with 0 % dietary inclusion level of WHM, and no Maxigrain® enzyme added; Diet 2 was the growers' diet with 10 % dietary inclusion level of WHM, and no Maxigrain® enzyme added; Diet 3 was the growers' diet with 20 % dietary inclusion level of WHM, and no Maxigrain® enzyme added; Diet 4 was the Control Diet with 0 % dietary inclusion level of WHM, and Maxigrain® enzyme added; Diet 5 was the growers' diet with 10 % dietary inclusion level of WHM, and Maxigrain® enzyme added; and Diet 6 was the growers' diet with 20 % dietary inclusion level of WHM, and Maxigrain® enzyme added. The percentage composition of the experimental diets for the growing pullets is shown in Table I.

The experiment lasted for 6 weeks, during which time food and water were supplied to the birds *ad libitum*. The birds were managed intensively under a deep litter system using the standard code of procedure as recommended for growing pullets by the Nigerian Institute of Animal Science (NIAS). Routine management operations such as daily removal of the left-over (uneaten) feed, washing of drinkers, provision of clean drinking water and general cleaning of the environment were carried out. The birds were also given standard medication and prophylactic treatments as recommended by the Nigerian Veterinary Medical Association (NVMA) for this region.

Nutrient digestibility trial

At the end of the 5^{th} week of the experiment (when the birds were 17 weeks old), two birds were selected per replicate and acclimatized to the metabolic cages for three days. This was followed by four days of faecal collection period using the total collection method, following the procedures of [19]. While the birds were in the metabolic cages, they were supplied with feed and water *ad libitum.* The droppings collected were wrapped in aluminium foils and oven-dried at 80^0C for about 24 hours to attain constant weights. The collections from each replicate group were then pooled together, weighed and representative samples taken for proximate analysis using the procedures of [13]. Apparent digestibility of nutrients (ADN) was calculated using the formula described by [20] thus:

$$\text{ADN} = \frac{(\text{Nutrient intake}) - (\text{Nutrient in droppings voided})}{\text{Nutrient intake}} \times 100$$

Total digestible nutrient (TDN) was calculated using the formula given by [21] as expressed below:

TDN = Digestible crude protein + Digestible NFE + 2.25 x Digestible either extract

Economy of feed conversion

Feed cost per bird was calculated by taking the total cost of all the ingredients that constituted the diets to get the feed cost per diet; cost of feed per kg live weight gain was calculated by determining the quantity of feed consumed by each bird in each of the dietary treatments, and dividing it by the body weight gain of the bird [22].

Other parameters were also calculated as follows:

Revenue = Final weight of birds (kg) x cost/kg weight of the birds (current market price)

Cost of production = Feed cost + other fixed and variable costs + cost of purchasing the birds

Gross margin = Revenue minus cost of production

Savings = Cost of production for the control birds minus cost of production for the treatment birds [22].

Table I: Composition of the experimental diets for growing pullets (13-18 weeks)

	Without enzyme			**With enzyme****		
WO replacement	**0 %**	**50 %**	**100 %**	**0 %**	**50 %**	**100 %**
Ingredients (%)	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5**	**Diet 6**
Maize	45.00	45.00	45.00	45.00	45.00	45.00
Groundnut cake	15.00	15.00	15.00	15.00	15.00	15.00
Palm kernel cake	8.00	8.00	8.00	8.00	8.00	8.00
Fish meal (65 % CP)	1.00	1.00	1.00	1.00	1.00	1.00
Wheat offal (WO)	20.00	10.00	0.00	20.00	10.00	0.00
WHM	0.00	10.00	20.00	0.00	10.00	20.00
Rice offal	4.90	4.90	4.90	4.90	4.90	4.90
Palm oil	1.00	1.00	1.00	1.00	1.00	1.00
Bone meal	2.50	2.50	2.50	2.50	2.50	2.50
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Lysine	0.30	0.30	0.30	0.30	0.30	0.30
Methionine	0.30	0.30	0.30	0.30	0.30	0.30
*Premix (Grower)	0.25	0.25	0.25	0.25	0.25	0.25
Common salt	0.25	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00	100.00

Calculated values

Crude protein (%)	16.56	16.22	15.88	16.56	16.22	15.88
Metabolizable energy(Kcal/kg)	2688	2701	2714	2688	2701	2714
Crude fibre (%)	6.52	7.60	8.68	6.52	7.60	8.68
Lysine (%)	0.96	0.96	0.96	0.96	0.96	0.96
Methionine (%)	0.57	0.57	0.57	0.57	0.57	0.57
Calcium (%)	1.48	1.48	1.48	1.48	1.48	1.48
Phosphorus (%)	0.89	0.89	0.89	0.89	0.89	0.89

**Each 2.5 kg of the Premix contains 12,000,000 IU vitamin A; 3,000,000 IU vitamin D3; 30,000 mg vitamin E; 2,500 mg vitamin K3; 1,000 mg folic acid; 40,000 mg niacin (B3); 2,000 mg vitamin B1; 5,000 mg vitamin B2; 10,000 mg pantothenic acid (B5); 3,500 mg B6; 20 mg B12; 80 mg biotin; 250 mg cobalt; 250 mg selenium; 1,200 mg iodine; 40,000 mg iron; 70,000 mg manganese; 8,000 mg copper; 60,000 mg zinc; 200,000 mg choline chloride; and 125,000 mg antioxidant.*

WHM = Water hyacinth meal

***Maxigrain® enzyme was added at the rate of 10 g/100 kg of the diet as a feed additive*

Chemical analysis
The experimental diets as well as the droppings collected during the nutrient digestibility trials were analyzed for their proximate composition using the standard procedures of [13].

Statistical analysis
Data collected were subjected to analysis of variance (ANOVA) by means of the General Linear Models (GLM) procedure of Statistical Analysis Software (SAS, 2000, Version 6, SAS Institute, Cary, NC, USA) based on the Completely Randomized Design using a 2 x 3 factorial arrangement (2 levels of enzyme and 3 levels of WHM). Where treatment or interaction means were significant, they were separated using the Duncan's Multiple Range Test [23].

RESULTS AND DISCUSSION

Composition of water hyacinth meal
The proximate composition of water hyacinth meal (WHM) collected at different periods of the year is shown in Table II. This result is similar to the results obtained by different workers [24, 25, 26 and 36] at different locations in Nigeria (Table III); except for the ash value obtained by [24] which was very low (2.71 %) when compared to the value obtained in this study (24.16 %). When the proximate composition of WHM is compared to that of wheat offal (Table IV), it can be seen that averagely, WHM has a higher CF content (21 % versus 11 %), lower CP content (14 % versus 16 %), higher ash content (24 % versus 6 %) and comparable ether extract (5 % versus 4 %) and metabolizable energy content (1901 kcal/kg versus 1845 kcal/kg). Therefore,

based on the similarity in the proximate composition of WHM and WO, it can be deduced that WHM may be used as a viable substitute for WO, to replace it when formulating diets for growing pullets.

On the mineral composition of WHM, the values obtained for K, Ca and Mg (1.02, 3.03 and 2.01 % respectively) as shown in Table V differs from the values obtained by [27] (4.61, 0.18 and 0.31 %) and [28] (4.28, 2.63 and 0.02 %) respectively. Also, the values obtained for Cu, Fe and Mn (0.46, 5.87 and 0.76 ppm) differs from the values obtained by [27] (20, 2557 and 222 ppm) respectively; while the Zn value (0.14 ppm) is lower than the value obtained by [28] (77.3 ppm). Hence, these results indicate that the mineral composition of water hyacinth varies from locality to locality, depending on the mineral composition of its immediate water vicinity. Scientists have discovered the potential of the plant to vigorously extract nutrients from its medium. It has high absorptive capacity, and functions as an effective mopping agent and scavenger of heavy metals like nickel, mercury and cadmium. It is also a good extractor of other chemical substances such as nitrates, phosphates, ammonia, silicate, chlorine and sulphur deposited in the aquatic habitat from industrial and domestic effluent, hence its use in biological waste water treatment and bioremediation [5]. For this Research Study, the water hyacinth meals used has low levels of heavy metals concentrations and are below the upper permissible limits as stipulated by the Food and Agricultural Organization/World Health Organization which are 300, 270 and 500 ppm respectively for Zn, Cu and Pb [29].

The anti-nutritional factors in WHM are presented in Table VI. The meal contains 0.26, 1.44, 2.24, 0.27 and 0.01 mg/100g saponin, tannin, oxalate, phytate and alkaloid respectively. WHM contains no hydrocyanic acid, flavonoids, resins, steroids and phenols. The levels of saponin, tannin, phytate and alkaloid in WHM are very low when compared to the levels commonly found in cereals and legumes and are below the recommended critical limits for these anti-nutritional factors [30]. Only oxalate is present in quantity that is slightly above the recommended critical limit (2.24mg/100g as against 0.54 mg/100g). According to [31], ingestion of forage containing a large quantity of soluble oxalate can result in Ca deficiency in animals due to formation of calcium oxalate in the intestines and the blood. However, WHM contains considerable amount of Ca (3.03 %, comparable to 32 g/kg DM obtained by [32]), which may compensate for losses caused by oxalate.

Table II: Proximate composition and metabolizable energy of water hyacinth meal collected at different periods of the year

Parameters	WHM 1* March	WHM 2* September	SEM	LOS	WHM (Average)
Dry matter	93.50	93.05	0.39	NS	93.28
Crude protein	13.74	14.02	0.09	NS	13.88
Crude fibre	22.79	20.06	1.12	NS	21.43
Ether extract	5.03	4.75	0.13	NS	4.89
Ash	23.50	24.81	0.44	NS	24.16
Nitrogen free extract	28.45	29.41	0.24	NS	28.92
**Metabolizable energy (Kcal/kg)	1902.20	1900.60	55.69	NS	1901.00

SEM = Standard error of the means
NS = not significant
**Average of two determinations carried out at random*
LOS = Level of significance
WHM = Water hyacinth meal
***Calculated values*

Table III: Proximate composition of water hyacinth meal (WHM) as determined by different workers at different locations in Nigeria

Parameter	Konyeme *et al.* (2006)	Olomu (2011)	Sotolu and Sule (2011)	Igbinosun and Talabi (1982)	Fasakin (2002)
Dry matter	89.50	85.40	Not stated	89.70	85.32
Crude protein	13.57	11.50	24.17	14.20	22.80
Crude fibre	21.60	19.90	19.62	20.40	15.00
Ether extract	4.49	2.00	2.37	3.30	4.82
Ash	2.71	14.90	11.35	27.20	12.40
NFE	47.33	37.10	42.49	24.60	30.30

Konyeme *et al.* (2006) at Kainji, Niger State
Olomu (2011) at Benin City, Edo State
Sotolu and Sule (2011) at Lafia, Nassarawa State
Igbinosun and Talabi (1982) at Lagos, Lagos State

NFE = Nitrogen free extracts

A breakdown analysis of the crude fibre of WHM shows that it is composed of 24.60 % cellulose, 26.08 % hemi-cellulose and 12.86 % lignin; with neutral detergent fibre (NDF) and acid detergent fibre (ADF) values of 63.54 and 37.46 % respectively (Table VII). These values compare favourably with the values of 62.3 (NDF) and 29.0 (ADF) respectively obtained by [33] for whole shoot water hyacinth collected from the rivers in the Mekong Delta of Vietnam; it also agrees with the findings of [34] that water hyacinth has a low ADF of 33 %. Also, the result of the CF analysis was close to those obtained by [35] in a review that covered water hyacinths collected from various sources all over the world. They reported cellulose 17.8 – 31 %; hemicellulose 22.0 – 43.4 % and lignin 7.0 – 26.36 %.

Table IV: Comparison of the proximate composition and metabolizable energy of water hyacinth meal (WHM) and wheat offal (WO)

Parameter	WHM[1]	WO*
Dry matter	93.28	90.70**
Crude protein	13.88	16.20
Ether extract	4.89	4.40
Crude fibre	21.43	11.30***
Ash	24.16	5.70
Nitrogen free extract (NFE)	28.92	61.80
Neutral detergent fibre (NDF)	63.54	60.00
Acid detergent fibre (ADF)	37.46	9.60
Acid detergent lignin (ADL)	12.86	2.00
Cellulose	24.60	7.60
Hemi-cellulose	26.08	50.40
Metabolizable energy (kCal/kg)	1901	1845**

[1]Result obtained is the average of the collections for the month of March and September.

*As reported by [37]

***As reported by [39]

**As reported by [38]

Table V: Mineral composition of water hyacinth meal

Mineral	Composition
Potassium (%)	1.02
Calcium (%)	3.03
Magnesium (%)	2.01
Zinc (ppm)	0.14
Copper (ppm)	0.46
Iron (ppm)	5.87
Manganese (ppm)	0.76
Lead (ppm)	0.10

Proximate composition of the experimental diets

The proximate composition of the experimental diets is shown in Table VIII. CP ranged from 16.68 % (Diet 3) to 17.30 % (Diet 1). These values are in agreement with the 16 % CP recommended for growing pullets of 8-16 weeks of age in the tropics by [25] and 15-16 % CP recommended for growing pullets between 9-20 weeks in the tropics by [40]. CF ranged from 6.33 % (Diet 1) to 9.81 % (Diet 6), which are less than the 10 % recommended tolerable limit of CF for pullets and laying hens; thus indicating the adequacy of the experimental diets in meeting the nutrient requirements of growing pullets.

Table VI: Anti-nutritional factors in water hyacinth meal

Anti-nutritional factors	Composition (mg/100g)	Recommended Critical Limit*
Saponin	0.26	7.02
Tannin	1.44	31.20
Oxalate	2.24	0.54
Phytate	0.27	23.40
Alkaloids	0.01	
Hydrocyanic acid	ND	
Flavonoids	ND	
Resins	ND	
Steroids	ND	
Phenols	ND	

*[30]
ND = Not detected

Table VII: Crude fibre composition of water hyacinth meal

Fibre component	**% Composition**
Neutral detergent fibre (NDF)	63.54
Acid detergent fibre (ADF)	37.46
Cellulose	24.60
Hemicellulose	26.08
Lignin (ADL)	12.86

Table VIII: Proximate composition of the experimental diets for growing pullets

		Without enzymes			**With enzymes**	
WO replacement	**0%**	**50%**	**100%**	**0%**	**50%**	**100%**
Parameter (%)	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**Diet 5**	**Diet 6**
Dry matter	86.6 0	90.48	89.26	89.56	90.67	90.31
Crude protein	17.30	17.25	16.68	17.29	17.24	16.70
Crude fibre	6.33	8.00	9.67	6.35	8.10	9.81
Ether extract	10.06	11.38	12.02	10.02	11.25	12.08
Ash	10.50	13.00	15.50	10.60	13.00	15.60
NFE	42.41	40.85	35.39	45.30	41.08	36.12

WO = Wheat offal NFE = Nitrogen free extracts

Growth performance of growing pullets

Feed intake was significantly (p<0.05) higher for birds fed the 10 and 20 % WHM diets than for birds fed the 0 % WHM diets; but there were no significant (p>0.05) differences in feed intake between the birds fed the enzyme-supplemented diets and those without enzyme supplementation (Table IX). This result differs from what was obtained by [41] when they fed 20 % and 40 % corn bran-based diets supplemented with and without Polyzyme® to broilers. Feed intake was significantly (p<0.05) higher in birds on the enzyme-supplemented diets compared to those on the basal diets or diets without enzyme supplementation. This may be due to the fact that exogenous enzymes supplement the digestive enzymes of monogastric animals by aiding the breakdown of NSPs, protein and anti-nutritional factors thereby increasing their nutritional value by making available the nutrients to the birds [42]. This result agrees with the findings of [43] when they evaluated the performance of pullets fed graded levels of rice offal supplemented with Roxazyme G® enzyme. They found that average feed intake significantly (p<0.05) increased as the dietary inclusion of rice offal increased with and without enzyme supplementation. This could be due to the fact that when fibrous feed ingredients are fed to birds, there is increase in feed intake resulting in birds trying to satisfy their energy requirements. WHM contains high fibre (about 21 %), which tends to increase the total fibre content of the diet, decrease the energy density of the diet and dilute other nutrients. Birds therefore would have to eat more to meet their energy requirements to sustain growth and development, hence the increased feed intake. This result also agrees with the earlier reports of [44] and [45] indicating that the enhanced feed intake at higher fibre levels was to compensate for the reduced energy density of such diets.

Final body weight and body weight gain of birds fed the 20 % dietary inclusion level of WHM was not significantly ($p>0.05$) different from those fed the 0 % dietary inclusion level of WHM; also body weight gain were significantly ($p<0.05$) higher for birds fed the enzyme-supplemented diets than for those fed diets without enzyme supplementation. This result differs from what was obtained by [43] when they fed diets containing 0, 20, 40 and 60 % rice offal to growing pullets; weight gain decreased with increase in the dietary inclusion level of rice offal. According to these researchers, high levels of inclusion of high fibre non-conventional feedstuff in poultry diets yielded negative responses in terms of weight gain because of increased fibre levels which tends to reduce nutrient utilization and precipitate metabolic dysfunction with attendant growth depression when ingested by non-ruminants [46]. In this Study, birds on the enzyme-supplemented diets showed higher weight gain than birds on the diets without enzyme supplementation supporting the fact that exogenous enzymes complement the digestive enzymes of poultry to enhance the utilization of NSPs in cereals and their by-products [47].

FCR was significantly ($p<0.05$) better for birds fed the enzyme supplemented diets (5.76) than for birds fed diets without enzyme supplementation (6.56); though there were no significant ($p>0.05$) differences in PER and ENE between birds fed enzyme-supplemented diets and those without enzyme supplementation. This result is similar to the findings of [48] who supplemented the Control Diet with three exogenous enzymes (Alquerzim®, Roxazyme G® and Feedzyme®) to observe their efficiency on broiler production. They found that FCR of broilers fed on enzymatic diets was better than those on the Control Diet. Similarly, other researchers [43] found that growing pullets given the enzyme-supplemented diets improved their feed conversion by 4.8 % compared to those in groups without supplement. They reported that feed conversion was improved due to better feed utilization by the birds. These observations are in line with the findings of [49] that when added to relevant poultry diets, NSP-degrading enzymes usually result in numerous beneficial effects, such as increased utilization of nutrients, improved apparent metabolizable energy (AME) values, increased growth rate, improved feed to gain ratio, decreased viscosity of intestinal digesta, reduced incidence of sticky excreta, improved litter conditions and reduced environmental pollution due to a decreased output of manure and gases such as ammonia.

Nutrient digestibility of growing pullets

DM digestibility increased with enzyme supplementation at 0 % WHM level; but at 10 % and 20 % WHM levels, there were no significant (p>0.05) differences in DM digestibility with or without enzyme supplementation. For CP. EE, ash and NFE digestibilities, there were no significant (p>0.05) differences between birds fed diets supplemented with exogenous enzymes and those without enzyme supplementation; but interaction effects was significant (p<0.05) for CP and EE digestibilities at 10 and 20 % WHM inclusion levels but was not significant for ash and NFE digestibilities at 10 and 20 % WHM inclusion levels (Table XI).This result is similar to the findings of [50] that apparent metabolizable energy (AME), lipid digestibility and protein digestibility were all significantly improved when arabinoxylanase and β-glucanase enzymes were added to wheat-soybean meal-based diets. [51] reported the effects of feeding graded levels of palm kernel meal (PKM) in broiler chicken diets supplemented with Maxigrain® enzyme where PKM treated with Maxigrain® was included at 10, 20, 30 and 40 % levels. The authors observed a significant (p<0.01) difference in protein, fat, NFE and ME retention in birds fed the Control and Maxigrain® treated diets than those on diets without Maxigrain®. For CF digestibility, birds fed on diets with exogenous enzyme supplementation performed significantly (p<0.05) better (76.17 %) than birds without enzyme supplementation (68.97 %). This result is also similar to what was obtained by [52] when he investigated the effect of Maxigrain® enzyme supplementation of sugarcane scrapping meal-based diets on the nutrient digestibility of laying Japanese quails (*Coturnix coturnix japonica*). The results showed that enzyme supplementation improved (p<0.05) significantly the digestibility of DM (62.21 vs. 63.03 and 63.28 %), CP (67.25 vs. 67.87 and 69.14 %), CF (70.19 vs. 78.14 and 81.66 %), EE (65.37 vs. 67.28 and 65.29 %), NFE (43.77 vs. 43.65 and 43.18 %), NDF (43.76 vs. 55.35 and 56.34 %), ADF (57.33 vs. 48.85 and 48.20 %) and ADL (39.40 vs. 48.34 and 48.31 %) for no enzyme, 100 ppm and 200 ppm enzyme supplemented diets respectively. At 0 % WHM dietary inclusion level, enzyme supplementation significantly (p<0.05) improved CF digestibility from 48.83 % to 65.80 %, but at 10 and 20 % dietary inclusion levels of WHM, enzyme supplementation had no significant ($p>0.05$) effect on CF digestibility. This could be due to the nature and enzyme composition of Maxigrain®. Each gramme contains 10, 000 IU cellulase, 200 IU β-glucanase, 10, 000 IU xylanase and 2, 500 FTU phytase. This enzyme composition may not be very effective in degrading the high cellulose (24.60 %), high hemicellulose (26.08 %) and high lignin (12.86 %) fibre component of WHM at high dietary inclusion levels of WHM (10 and 20 %) in growing pullet diets, hence the non-significant difference in CF digestibility among the birds fed those diets.

Economy of feed conversion of growing pullets

For the growing pullets, the economy of feed conversion is shown in Table XII. Cost of feed consumed/bird was significantly ($p<0.05$) lower for birds fed on diets with exogenous enzyme supplementation than for birds fed on diets without exogenous enzyme supplementation. This could be due to the fact that exogenous enzymes improved the birds' performance by improving nutrient digestibility, making the nutrients more available to the birds, hence improving profitability through feed cost savings. This improved utilization of fibrous feedstuffs is achieved partially by a reduction of the viscosity of the intestinal digesta [49, 53].

Cost of feed/kg live weight gain was significantly ($p<0.05$) lower for the 0 % dietary inclusion level of WHM than for the 10 and 20 % dietary inclusion levels; but there was no significant ($p<0.05$) difference in gross margin/bird between the 0 and 20 % dietary inclusion level of WHM. This result is similar to the result obtained by [43] when they fed pullets with graded levels of rice offal supplemented with Roxazyme G® enzyme. Cost of feed/kg for diets with 0, 20, 40 and 60 % levels of rice offal without enzyme supplementation was ₦249.18, ₦187.37, ₦163.24 and ₦115.05 respectively; while for diets with enzyme supplementation, cost of feed/kg for diets containing 0, 20, 40 and 60 % levels of rice offal was ₦248.59, ₦189.05, ₦153.35 and ₦111.25 respectively. This clearly shows the decrease in cost/kg diet as the dietary level of rice offal increased, indicating the effectiveness of rice offal as a cheaper alternative fibrous feedstuff in the diet of pullets. The same can be said for WHM in this Study; hence the similarity in GM/bird between birds fed 0 and 20 % dietary inclusion levels of WHM.

Table IX: Main effects of exogenous enzymes supplementation and feeding graded levels of water hyacinth meal on the growth performance of growing pullets

Treatment	Initial BW (g)	Final BW (g)	Total BWG (g)	Weekly BWG (g)	Total FI (g)	Weekly FI (g)	FCR	PER	Energy Eff.	Mortality
ENZYME (E)										
0	798.33	1223.16	424.82[b]	70.80[b]	2678.95	446.49	6.56[b]	0.84	0.59	0.00
1	787.41	1266.51	479.10[a]	79.85[a]	2730.83	455.14	5.76[a]	0.86	0.64	0.74
SEM	22.01	22.06	23.80	3.97	28.68	4.78	0.35	0.04	0.03	0.74
LOS (0.05)	NS	NS	*	*	NS	NS	*	NS	NS	NS
HYACINTH (H)										
0%	789.73	1299.22[a]	509.50[a]	84.92[a]	2601.02[b]	433.51[b]	5.13[a]	0.97[a]	0.74[a]	1.11
10%	787.78	1183.06[b]	395.28[b]	65.88[b]	2762.83[a]	460.47[a]	7.06[b]	0.74[b]	0.51[c]	0.00
20%	801.11	1252.22[a]	451.11[ab]	75.19[ab]	2750.83[a]	458.47[a]	6.29[b]	0.84[b]	0.60[b]	0.00
SEM	26.96	27.02	29.15	4.86	35.13	5.86	0.43	0.05	0.03	0.91
LOS (0.05)	NS	*	*	*	*	*	*	*	*	NS
INTERACTION										
E X H	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a b c]Means in the same column with different superscripts were significantly ($p<0.05$) different

SEM = Standard error of the means LOS = Level of significance NS = not significantly different Wkly = Weekly FI = Feed intake
BW = Body weight Eff. = Efficiency BWG = Body weight gain FCR = Feed conversion ratio PER = Protein efficiency ratio

Table X: Main effects of exogenous enzymes supplementation and feeding graded levels of water hyacinth meal on the nutrient digestibility of growing pullets (%)

Treatment	Dry matter	Crude Protein	Crude Fibre	Ether Extract	Ash	NFE	TDN
ENZYME (E)							
0	87.22	89.35	68.97[b]	95.47	79.06	89.67	76.05[a]
1	87.30	89.03	76.17[a]	94.24	80.29	88.93	71.03[b]
SEM	1.06	0.79	2.43	0.69	1.55	0.88	0.70
LOS (0.05)	NS	NS	*	NS	NS	NS	*
HYACINTH (H)							
0%	86.72	87.44[b]	57.32[b]	95.43[a]	78.62	89.71	76.52[a]
10%	88.40	90.64[a]	81.65[a]	95.93[a]	82.05	89.09	74.64[b]
20%	86.66	89.49[ab]	78.74[a]	93.19[b]	78.35	89.11	69.47[c]
SEM	1.30	0.96	2.97	0.85	1.89	1.08	0.85
LOS (0.05)	NS	*	*	*	NS	NS	*
INTERACTION							
E X H	*	*	*	*	NS	NS	*

[a b c] *Means in the same column with different superscripts were significantly (p<0.05) different*

SEM = Standard error of the means *LOS = Level of significance* *NS = not significantly different*
NFE = Nitrogen free extracts *TDN = Total digestible nutrient*

Table XI: Interaction effects of exogenous enzymes supplementation and feeding graded levels of water hyacinth meal on the nutrient digestibility of growing pullets (%)

Treatment	Dry matter	Crude protein	Crude fibre	Ether extract	Total Digestible Nutrient (TDN)
Diet 1	84.58^{b}	86.12^{c}	48.83^{c}	94.25^{a}	75.53^{ab}
Diet 2	88.82^{a}	90.65^{ab}	78.96^{a}	96.47^{a}	77.99^{a}
Diet 3	88.27^{ab}	91.27^{a}	79.11^{a}	95.39^{a}	71.28^{c}
Diet 4	88.86^{a}	88.76^{abc}	65.80^{b}	96.61^{a}	77.52^{a}
Diet 5	87.98^{ab}	90.63^{ab}	84.34^{a}	95.67^{a}	74.63^{b}
Diet 6	85.06^{ab}	87.71^{bc}	78.38^{a}	90.71^{b}	64.30^{d}
SEM	2.01	1.49	5.40	1.31	0.38
LOS (0.05)	*	*	*	*	*

[a b c]Means in the same column with different superscripts were significantly (p<0.05) different

Diet 1 = 0 % WHM; no Maxigrain® enzyme added
Diet 2 = 10 % WHM; no Maxigrain® enzyme added
Diet 3 = 20 % WHM; no Maxigrain® enzyme added
Diet 4 = 0 % WHM; Maxigrain® enzyme added
Diet 5 = 10 % WHM; Maxigrain® enzyme added
Diet 6 = 20 % WHM; Maxigrain® enzyme added
WHM = Water hyacinth meal
LOS = Level of significance
SEM = Standard error of the means

Table XII: Main effects of exogenous enzymes supplementation and feeding graded levels of water hyacinth meal on the economy of feed conversion of growing pullets

Treatment	Cost of feed consumed/bird (₦)	Cost of feed/kg live weight gain (₦)	Gross margin/bird (₦)
ENZYME (E)			
0	212.45[b]	497.31	153.36
1	203.70[a]	447.65	175.66
SEM	2.37	25.62	17.26
LOS (0.05)	*	NS	NS
HYACINTH (H)			
0%	206.10	407.08[a]	206.94[a]
10%	208.97	533.41[b]	119.17[b]
20%	209.14	476.96[b]	167.42[a]
SEM	2.90	31.38	21.14
LOS (0.05)	NS	*	*
INTERACTION			
E X H	NS	NS	NS

[a b c]Means in the same column with different superscripts were significantly (p<0.05) different

SEM = Standard error of the means *LOS = Level of significance* *NS = not significantly different*

CONCLUSION AND RECOMMENDATIONS

Feed intake was significantly ($p<0.05$) higher for birds fed the 10 and 20 % WHM diets than for birds fed the 0 % WHM diets. There were no significant ($p>0.05$) differences in feed intake between the birds fed the enzyme-supplemented diets and those without enzyme supplementation. Final body weight and body weight gain of birds fed the 20 % dietary inclusion level of WHM was not significantly ($p>0.05$) different from those fed the 0 % dietary inclusion level of WHM. Also body weight gain were significantly ($p<0.05$) higher for birds fed the enzyme-supplemented diets than for those fed diets without enzyme supplementation. FCR was significantly ($p<0.05$) better for birds fed the enzyme supplemented diets (5.76) than for birds fed diets without enzyme supplementation (6.56). There were no significant ($p>0.05$) differences in PER, ENE and mortality between birds fed enzyme-supplemented diets and those without enzyme supplementation. Hence, WHM can be included up to 20 % in the diets of growing pullets (replacing 100 % wheat offal) with no detrimental effects on growth performance and nutrient digestibility; though better results were obtained with exogenous enzyme supplementation. A noxious weed that requires millions of dollars for its eradication and control can now be converted into an important and valuable feed resource for poultry. It is available in commercial quantities throughout the year and should now be regarded as a valuable raw material vital to the Nigerian feed milling industry for the formulation of balanced and quality feed for growing pullets at reduced cost.

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