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Inclusion of Water Hyacinth Meal in Broiler Chicken Diets: Potential on the Production Performance and Cell-mediated Immunity

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Abstract

Water hyacinth (*Eichhornia crassipes)* is popular for both water gardeners and aquarists because it is one of only a few floating aquatic plants. However, it is also considered invasive aquatic weed plants in tropical and subtropical regions, and many attempts have been made to eradicate or control these plants. A feeding trial was conducted to explore the potential of water hyacinth meal (WHM) on growth performance, economic viability, and cell-mediated immunity of broiler chickens in a 42-day feeding trial. Sixty-one-day-old broiler chickens were randomly allotted to 4 treatment groups: (T_1) 0% WHM, (T_2) 2.5% WHM, (T_3) 5.0% WHM and (T_4) 7.5% WHM, replicated thrice with five birds each replication arranged in a Completely Randomized Design (CRD) experimental set-up. Results revealed no significant difference (P>0.05) on the bi-weekly body weight gain (BWG), average daily gain (ADG), and feed conversion ratio. Numerically, Treatment 2 showed the highest final body weight (1545.33± 36.37 g/bird), while the control showed the lowest value (1076.00±109.23g/bird). A significant effect (P<0.05) was observed on the voluntary feed intake (VFI), and cell-mediated immunity of broiler chicken fed diets containing WHM. Moreover, the highest gross return results in T_2 leads to the highest overall return input cost per chicken, and experimental birds without WHM has the lowest income generated. In conclusion, a noxious water weed could be incorporated into the diet with no adverse effect on broiler production performance.

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Introduction

Broiler chicken production is one of the top priorities in animal enterprises in the Philippines today. Due to its increasing demand, the industrial adaptation in this particular agricultural sector has given importance because of its economic result. Since chicken producers have drawn interest in lesser production cost but good quality of their products, they focus on selecting good breeds and feeds of high quality and nutritional value but in local conditions. Moreover, feeding makes up the major cost of poultry production. It plays an essential factor in raising chickens. Thus, nutrition is reflected in bird's growth performance and their products (Fanatico, 2003). The use of alternative domestic feeds, antibiotics, and supplements has become the focus of researches. Some studies use medicinal herbs, grass, spices, beans, nuts, tree crops, and agricultural wastes as an alternative in synthesized inputs. However, few studies were conducted using water weeds.

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is popular for both water gardeners and aquarists because it is one of a few floating aquatic plants (Keller and Lodge 2009). However, some treated it as the world's worst aquatic weed plant (Indulekha *et al.,* 2019), proliferating in most tropical countries (Adeyemi and Osubor, 2016). It was estimated that ten plants could produce 600,000 seeds during an eight-month growing season and completely covered 0.4 hectare of a natural freshwater surface (Vymazal 2008). With this, certain approaches have been tried to control and eradicate the weed in collaborated efforts. Unfortunately, the plants invasive behavior and fast expansion rate brought them unsuccessful (Anteneh *et al.,* 2014). However, another method was considered to maximize its potential. An alternate option is to utilize water hyacinth for various purposes, such as animal feed (Jafari, 2010). A careful biochemistry and physiology analysis of water hyacinth recommends its potential as a raw material in some industries. These plants are utilized for animal consumption because of its availability and nutrient value (Simpson and Sanderson 2002). Its proximate analysis revealed that water hyacinth is constituted of 50% protein and 33% carbohydrates, while the remaining nutrients are made up of fat, ash, and fiber (Adeyemi and Osubor 2016).

Moreover, water hyacinth leaf protein concentrate (WHPLC) may be used as food supplements due to the high protein content and sufficient content of xanthophylls, carotenes, unsaturated fats, starch, and essential minerals such as calcium, phosphorus, and iron (Kateregga and Sterner 2007). Seventeen out of twenty amino acids were detected in the water weed without asparagine, glutamine, and tryptophan (Adeyemi and Osubor 2016). Several studies reported different amounts of crude protein in water hyacinth: 32.9% (Wolverton and Mcdonald 1978), 23.82% (Alkassar and Al-Shukri, 2018), 15.27% (Okoye *et al.,* 2000), and 18.7% (Monsod, 1978). The various results might be caused by the difference in the potential biotic and abiotic factors present in the water where they grow. Evidence from the study of Adeyemi and Osubor (2016) stated that levels of all heavy metals were found to be within the safe limit, which disclosed the water hyacinth to be acutely nontoxic. However, literature was inadequate in terms of profound details and further studies with the extraction of these water weeds in edible form. Hence, to utilize the abundant water weeds in the community, this study was conducted to evaluate the growth performance, economic viability, and the cell-mediated immunity of broiler chickens fed with water hyacinth meal.

Materials and methods

Experimental birds, management and diets

All procedures used in the study are in accordance with the Good Animal Husbandry practices in the Philippines. A total of 60 one-day-old broiler chicks were purchased from a local commercial hatchery and brooded for two weeks before the experimental period. After the brooding period, the experimental birds were randomly allotted into four dietary treatments replicated thrice with five birds in every replication and arranged in a Completely Randomized Design (CRD) experimental set-up. The experimental diets and clean drinking water were offered *ad-libitum* daily. Broiler starter mash was fed from 15-28 days and gradually shifted to finisher mash from 29-42 days.

Experimental diets were formulated to contain 0% WHM (T_1), 2.5%WHM (T_2), 5%WHM (T_3), and 7.5%WHM (T_4) at the starter and finisher phases considering the nutrient requirements based on the Philippines Recommends for Livestock Formulation. All experimental diets were subjected to proximate analysis (Table 1 and 2), following the methods described by the AOAC (2016). Cleaned and disinfected cages measured 1 square foot per chick with good ventilation, and proper heat conversion was constructed a week before the arrival of the experimental birds.

Preparation of water hyacinth meal (WHM)

Whole plants of water hyacinth were collected fresh from the two lakes of Lake Seloton and Lake Sebu in South Cotabato. Collected plants were washed and scrutinized to remove all unwanted matters (lake debris, leather wrappings, and other extraneous materials), cut manually, and sundried for three days to reach 10% moisture content (Alkassar and Al-Shukri, 2018). Dried plants were ground using an attrition mill and sieved through a 1 mm sieve to produce water hyacinth meal and stored in large plastic containers with tight-fitting lids until needed.

Growth performance

The body weight gain was calculated by getting the difference in average initial weight and the average final weight of broilers. The initial weight was recorded at the start of the feeding trial (right after the brooding period). In contrast, the final weight was determined after the 42-day feeding trial, and experimental birds were fasted for a period of 12 h before weighing. Bi-weekly body weight gain (BWG) was measured every two weeks to monitor its weight gain. The feed intake of broilers was recorded by offering a weighed quantity of feed and weighing feed refused daily. The feed conversion ratio (FCR) was calculated by getting the percentage of the feed consumed over the broilers final body weight gain. A digital weighing scale with a maximum capacity of 3 kg and a division of 0.1 g was used in measuring parameters in weight.

Slaughtering and Cell-mediated immunity evaluation

At day 42, all experimental birds were abstained from feeds for a period of 12 h to guarantee the emptiness of the gastrointestinal tract. One bird per treatment in each replication, having a final weight close to each replication's average body weight, was slaughtered (Haruna and Odunsi, 2018). Chosen birds were properly bled by slitting the jugular vein to facilitate bleeding and searing with hot water at 60°C. After defeathering, birds were eviscerated to measure spleen and bursa's weight to evaluate the broilers immune response. The cell-mediated immunity was determined by measuring the spleen and bursa indices. Spleen index is expressed by dividing the spleen weight over the total body weight. In contrast, the bursa index is calculated by weighing the bursa of Fabricius divided by the total body weight of broiler chicken (Latif *et al.,* 2014). Both spleen and bursa indices are expressed in percentages.

$$Spleen\ Index = \frac{Spleen\ Weight}{Body\ Weight} x\ 100$$

$$Bursa\ Index \frac{Weight\ of\ Bursa}{Body\ Weight} x\ 100$$

Cost and return analysis

The return above feed and chick cost (RAFCC) was calculated by subtracting the cost of inputs (chicks and feeds expenses) from the bird sales at the termination of the study. Return on Investment (ROI) measures the gain or loss generated to study and is usually expressed as a percentage of net income over the capital.

Statistical analysis

One-way analysis of variance (ANOVA) was used to analyze the data gathered, and the means were compared using Tukey's Honest Significant Difference (HSD). Data analysis was performed using the Statistical Package of Social Science software of version 17.0. A p-value of 0.05 or less was considered significant. The mean average daily gain weight was presented using the Sigma Plot computer software version 17.

Results

Proximate analysis of water hyacinth meal

Based on the analysis, the water hyacinth meal contains 7.41% crude protein, 30.45% crude fiber, and 15.06% ash (Table 3).

Growth performance

Table 4 summarizes the effects of different measured levels of water hyacinth meal (WHM) on broiler chicken in terms of the live body weight, weight gain, feed intake, and feed conversion ratio. The interaction effect of the different levels of water hyacinth meal (WHM) in chicken diets to the final weight and weight gain showed not significantly different ($P>0.05$) for the entire phases, where T_2 gained the most weight of 43.55±1.32 g average daily gain (ADG) and the control recorded the lowest ADG of 38.43±3.90 g. Feeding broilers with graded levels of WHM had no significant effect on weight gain and feed conversion ratio to both starter and finisher phases. However, numerically, birds fed with various levels of WHM revealed higher weight gain and feed conversion ratio than the control.

Same as with the voluntary feed intake (VFI), control (1823.13±101.22 g) was found to be less feed intake than with the WHM-supplemented rations where T_2 (2143.47±40.30 g) has the highest VFI. Feed intake was not significantly influenced ($P>0.05$) during the starter phase (15-28 days). Meanwhile, during the finisher phase (29-42 days), broiler chickens' feed intake was significantly affected. Throughout the feeding trial, graded levels of WHM revealed a significant difference ($P<0.05$) on feed intake.

Table 1. Composition and Chemical Analysis of Starter Ration.

Ingredients (% as fed basis)	Starter Diets (15-28 days)			
	T_1	T_2	T_3	T_4
	0%	2.5%	5%	7.5%
Hammered Corn	55.00	54.00	53.00	52.00
Rice Bran D_1	9.00	8.25	7.50	7.00
Soybean, US	29.74	29.10	28.48	27.80
Fish meal, 60%	2.00	2.00	2.00	2.00
Water Hyacinth Meal	0.00	2.50	5.00	7.50
Dicalcium phosphate	1.35	1.30	1.25	1.20
Limestone	0.86	0.77	0.68	0.57
Lysine HCL	0.10	0.10	0.10	0.10
D-L Methionine	0.10	0.10	0.10	0.10
L threonine	0.10	0.10	0.10	0.10
Vitamin Premix*	0.91	0.72	0.51	0.19
Salt	0.65	0.65	0.65	0.65
Vegetable Oil	0.19	0.41	0.63	0.79
Chemical Analysis (%DM)				
Crude Protein	20.84	20.40	20.88	20.53
Crude Fiber	4.06	7.05	6.45	6.02
Ash	7.65	7.81	6.64	6.85
Moisture	12.58	12.22	12.09	12.34
Calculated Analysis				
Metabolizable Energy	2900.66	2900.22	2900.27	2900.04
Calcium	0.87	0.87	0.87	0.87
Phosphorus	0.44	0.44	0.44	0.44
Methionine	0.46	0.49	0.51	0.54
Lysine	1.27	1.34	1.40	1.47
Threonine	0.91	0.95	1.00	1.05
Meth + Cys	0.73	0.73	0.73	0.73
Tryptophan	0.25	0.25	0.24	0.24

*Vit. A 12000000 iu, Vit D3 2000000 iu, Vit E 15000 mg, Vit K3 2000 mg, Vit C 10000 mg, Vit B1 2000 mg, Vit B2 4000 mg, Vit B6 3000 mg, Vit B12 25000 mg, Folic Acid 700 mg, Panthothenic Acid 15000 mg, Biotin 10000 mg, Niacin 25000 mg, Antioxidant 1000 mg, Magnesium 250000 mg, Zinc 50000 mg, Iron 25000 mg, Manganese 10000 mg, Copper 2000 mg, Iodine 500 mg, Selenium 500 mg, Cobalt 5 mg, Lysine 2500 mg, DL-Methionine 8500 mg, Probiotics 50000 mg.

Immune response

In the present study, the lymphoid organs (bursa and spleen) weights and immune organ indices were assayed to investigate the broiler chickens cell-mediated immunity.

The weights of the immune organs were not affected by the WHM when incorporated in the diets (Table 5). Numerically, there is clear evidence that spleen and bursa weights increased values from the control to T_4 as WHM is incorporated at higher levels in the diet. In this study, no significant difference (P>0.05) were observed in the spleen index, where Treatment 1 (Control) and Treatment 2 (2.5% WHM) were identified as the lower computed indices than Treatment 3 (5% WHM) and 4 (7.5% WHM). However, in the bursa index, T_3 and T_4 showed a significant increased (P<0.05) than the control.

Table 2. Composition and Chemical Analysis of Finisher Ration.

Ingredients (% as fed basis)	Finisher Diets (29-42 days)			
	T_1	T_2	T_3	T_4
	0%	2.5%	5%	7.5%
Hammered Corn	57.00	56.00	54.25	53.00
Rice Bran D_1	9.00	9.00	9.00	9.00
Soybean, US	26.41	25.58	24.90	24.12
Fish meal, 60%	2.00	2.00	2.00	2.00
Water Hyacinth Meal	0.00	2.50	5.00	7.50
Dicalcium phosphate	1.25	1.17	1.15	1.10
Limestone	0.80	0.73	0.60	0.50
Lysine HCL	0.10	0.10	0.10	0.10
D-L Methionine	0.10	0.10	0.10	0.10
L threonine	0.10	0.10	0.10	0.10
Vitamin Premix*	1.61	1.03	0.78	0.31
Salt	1.25	1.25	1.25	1.25
Vegetable Oil	0.38	0.44	0.77	0.92
Chemical Analysis (%DM)				
Crude Protein	19.72	19.08	19.97	19.19
Crude Fiber	4.43	4.62	6.82	11.28
Ash	7.98	8.07	6.47	6.52
Moisture	11.92	12.38	11.81	11.76
Calculated Analysis				
Metabolizable Energy	2900.57	2900.61	2900.45	2900.42
Calcium	0.81	0.81	0.81	0.81
Phosphorus	0.41	0.41	0.41	0.41
Methionine	0.44	0.47	0.49	0.52
Lysine	1.17	1.24	1.31	1.37
Threonine	0.85	0.90	0.95	0.99
Meth + Cys	0.69	0.69	0.69	0.69
Tryptophan	0.23	0.23	0.22	0.22

*Vit. A 12000000 iu, Vit D3 2000000 iu, Vit E 15000 mg, Vit K3 2000 mg, Vit C 10000 mg, Vit B1 2000 mg, Vit B2 4000 mg, Vit B6 3000 mg, Vit B12 25000 mg, Folic Acid 700 mg, Panthothenic Acid 15000 mg, Biotin 10000 mg, Niacin 25000 mg, Antioxidant 1000 mg, Magnesium 250000 mg, Zinc 50000 mg, Iron 25000 mg, Manganese 10000 mg, Copper 2000 mg, Iodine 500 mg, Selenium 500 mg, Cobalt 5 mg, Lysine 2500 mg, DL-Methionine 8500 mg, Probiotics 50000 mg.

Return on investments

Final weights per treatment were measured where T_2 (1,545.33± 36.37 g/bird) has the highest final weight recorded followed by T_4 (1,472.93±130.15 g/bird) and T_3 (1,450.87± 16.01 g/bird) while the control showed the lowest value of 1,404.73± 85.99 g/bird (Table 6). With the same amount of price per kilo (Php130/kg), T_2 revealed to be a potential asset for a higher market with 200.89 Php gross income per chicken compared to the control with 182.61 Php/chicken. In terms of the total feed cost, feed diets incorporated with water hyacinth meal have a lower cost per kilo than the control. With this result, T_2 showed the highest return above chick and feed cost amounting to 104.99 Php per chicken compared to the control with 92.50 Php per chicken.

Table 3. Proximate analysis of Water Hyacinth Meal on a Dry Matter basis.

NUTRIENT	WHM (%)
Crude Protein, %	7.41
Crude Fiber, %	30.45
Ash	15.06

The analysis was performed in triplicate samples following the methods described by the AOAC (2016) 20th edition.

Discussion

Proximate analysis of water hyacinth meal

The Crude protein content of the water hyacinth meal revealed lower compared to the studies of Wolverton *et al.* (1978), Alkassar and Al-Shukri (2018), Okoye *et al.* (2000), and Monsod (1978) with 32.9 %, 23.82%, 15.27%, and 18.7%, respectively. The contradicting results might be caused by the difference in the potential biotic and abiotic factors present in the water where they grow. Basically, crude protein levels play an essential role in poultry nutrition. It depends on the nitrogen (N) content of the food proteins, which become deficient only when organic matter with high carbon content is involved.

Table 4. Effects of the dietary inclusion of water hyacinth meal on the growth performance of broiler chicken.

PARAMETERS (days)	TREATMENTS					
	T1 0%	T2 2.5%	T3 5%	T4 7.5%	CV[1]	p -value
Final Weight (g)						
15-28	777.47 ± 38.23	789.13± 24.30	817.33± 6.52	804.33±48.71	*4.19*	0.521^{ns}
29-42	1404.73± 85.99	1545.33± 36.37	1450.87± 16.01	1472.93±130.15	*5.48*	0.266^{ns}
15-42	1404.73± 85.99	1545.33± 36.37	1450.87± 16.01	1472.93±130.15	*5.48*	0.266^{ns}
Body weight gain (g)						
15-28	448.73±52.81	463.07±24.30	485.80±7.99	477.73±49.25	*8.17*	0.663^{ns}
29-42	627.27±85.51	756.20±48.94	633.53±22.12	668.60±92.16	*10.18*	0.158^{ns}
15-42	1076.00±109.23	1219.27±36.86	1119.33±5.89	1146.33±131.89	*7.713*	0.311^{ns}
Voluntary Feed Intake (g)						
15-28	821.07±58.52	929.53±13.07	868.73±52.52	889.33±36.19	*4.99*	0.084^{ns}
29-42	1002.07 ± 68.41^{b}	1213.93 ± 31.87^{a}	1167.20 ± 130.29^{ab}	1252.53 ± 6.06^{a}	*6.50*	0.016^{*}
15-42	1823.13 ± 101.22^{b}	2143.47 ± 40.30^{a}	2035.93 ± 104.54^{a}	2141.87 ± 34.23^{a}	*3.80*	0.003^{**}
Feed Conversion Ratio						
15-28	1.84±0.21	2.01±0.10	1.79±0.13	1.87±0.21	*8.90*	0.462^{ns}
29-42	1.61±0.22	1.61±0.06	1.85±0.26	1.90±0.24	*12.17*	0.280^{ns}
15-42	1.70±0.09	1.76±0.03	1.82±0.12	1.88±0.18	*6.61*	0.333^{ns}

[1]CV: Coefficient of Variance

[a,b] Means±SD with different superscripts in the same row differ significantly ($P<0.05$).

Moreover, the water hyacinth meal's crude fiber content in the study contains as high as 30.45%. The crude fiber in poultry nutrition is often related to reduce energy availability due to its minor role as an energy source and interference with digestive processes. Moderate amounts of fiber may promote a benefit for gastrointestinal development, thereby enhancing growth performance (de Vries, 2015). The ash content is 15.06% and showed to be sufficient where normal ash content of forage for animal nutrition is between 9 to 18% in the Dry Matter basis (Hoffman, 2005).

Growth performance

In the present study, broiler production performance except the feed intake was not significantly affected ($P>0.05$) when the water hyacinth meal was incorporated in the diets. Numerically, birds fed with water hyacinth meal had a higher weight gain than birds fed with the diets without WHM (control). These results may be due to the type of balance between the nutritional value present in the water hyacinth meal and the nutrients from the rest of the feed ingredients, including amino acids, which greatly benefited the bird's body shown in their growth performance. However, it is observed that T_3 and T_4 had a lower body weight gain compared to T_2. One of the reasons for the lower yield of T_3 and T_4 is the high percentage of raw fibers caused by the slowing down in the inhibition of growth rates and weight gain. This may be due to the presence of a high proportion of tannin in the plant. The more amount of WHM added, the more tannin content served on the bird's diets. Excessive amounts of tannin resulted in improper digestion of some minerals necessary for metabolism, which eventually led to a decline in the growth rate (Alkassar and Al-Shukri, 2018). Moreover, plants with tannin as animal antimicrobial agents, reducing the digestion of the diet and the consumption of feed (Medugu *et al.,* 2012).

Table 5. Effects of the dietary inclusion of water hyacinth meal on the cell-mediated immunity of broiler chicken.

LYMPHOID ORGANS	TREATMENT					
	T_1 0%	T_2 2.5%	T_3 5%	T_4 7.5%	CV[1]	*p-value*
Spleen wt. (g)	2.00±0.346	1.80±0.917	2.30±0.100	2.30±0.557	26.94	0.655^{ns}
Bursa wt. (g)	0.57±0.115	0.63±0.115	0.83±0.115	0.77±0.115	16.29	0.077^{ns}
Spleen Index (g)	0.14±0.026	0.12 ±0.060	0.16 ±0.007	0.16±0.028	22.07	0.514^{ns}
Bursa Index (g)	0.04 ± 0.006^{b}	0.04 ± 0.007^{ab}	0.06 ± 0.008^{a}	0.05 ± 0.003^{ab}	0.000	0.026*

[1]CV: Coefficient of Variance

[a,b] Means±SD with different superscripts in the same row differ significantly ($p<0.05$).

Previous data on growth performance results were correlated with the data of the voluntary feed intakes (VFI), where T2 showed the highest VFI, and control recorded the lowest feed intake. This might be due to the effect of the WHM, which offered a taste that is more responsive to chicken. Broiler chickens are said to have more taste buds than the layer-type are more sensitive to taste stimuli (Liu *et al.,* 2018). These results were consistent with Lopez (1979), who reported that intake rates accelerated as a water hyacinth meal was added to the feed composition. This could be attributed to the incorporation of WHM in broiler diets, where they tend to eat more to satisfy their energy requirements.

Table 6. Return above feed and chick cost of broiler chicken fed with water hyacinth meal.

PARTICULARS	TREATMENTS			
	T_1 0%	T_2 2.5%	T_3 5%	T_4 7.5%
Final live weight, (g)	1404.73	1545.33	1450.87	1472.93
Price/kg live weight (Php)	130.00	130.00	130.00	130.00
Gross return/head (Php)	182.61	200.89	188.61	191.48
Cost of DOC[1]/head (Php)	30.00	30.00	30.00	30.00
Feed Consumption (kg/head)				
a. CBM[2] (kg)	0.48	0.48	0.48	0.48
b. Starter ration (kg)	0.82	0.93	0.87	0.89
c. Finisher ration (kg)	1.00	1.21	1.17	1.25
Price/kg of Feed (Php)				
a. CBM[2] (Php)	32.50	32.50	32.50	32.50
b. Starter ration (Php)	24.12	23.51	22.87	22.05
c. Finisher ration (Php)	24.73	23.50	22.88	21.86
Total Feed Cost (Php)				
a. CBM[2] (Php)	15.60	15.60	15.60	15.60
b. Starter ration (Php)	19.78	21.86	19.90	19.62
c. Finisher ration (Php)	24.73	28.44	26.77	27.33
Total Cost (Php)	90.11	95.90	92.27	92.55
RAFCC[3] (Php)	92.50	104.99	96.34	98.93

[1]DOC = Day Old Chick

[2]CBM = Chick Booster Mash

[3]RAFCC = Return Above Feed and Chick Cost.

Statistical analysis showed significant differences (P>0.05) in voluntary feed intake between the control and the rest of the treatments. The values of T_2 that are shown to be consistently higher may be due to the possibility that the birds under this treatment have a higher degree of balance in the diet's amino acid ratios composed of an ideal amount of WHM where the higher biological value of the diet is reflected. On the other side of poultry production, feed conversion ratio (FCR) plays a vital role in measuring broilers performance. FCR is a rate measuring the efficiency with which the bodies of livestock convert animal feed into the desired output, which means that the lower the value, the more efficient the birds are in converting feed to live weight (Ampode *et al.,* 2020). However, this study's feed conversion ratio showed that values are accelerating as the level of WHM increase

Cell-mediated immune response

The spleen and bursa of Fabricius are the immune organs of the avians, including chickens. It has been assumed traditionally that the relationship between spleen (and bursa) size and the immune system provides solid evidence for their correlation validity. The larger spleen and bursa sizes represented a strong immune system (Smith, 2004). Since immunity was focused on the present study, the spleen index revealed to be not significantly influenced. However, table 5 showed an increasing value for control (0% WHM) to T_4 (7.5% WHM). However, the bursa index showed significantly different (P<0.05) compared to other treatments. The results obtained in the current study are in concurrence with the report of Alkassar and Al-Shukri (2018), who reported that immune response increased with an increase in dietary levels of WHM was incorporated in poultry diet. It was also reported that the indices of both the spleen and the bursa determine the immunity response. The larger the immunity index, the higher the immune strength. The data showed that a statement might represent that the more water hyacinth meal added, the stronger the immune system it could offer. As discussed previously, the water hyacinth meal also has antibacterial and anti-fungal properties, which may further enhance the immune system's activity.

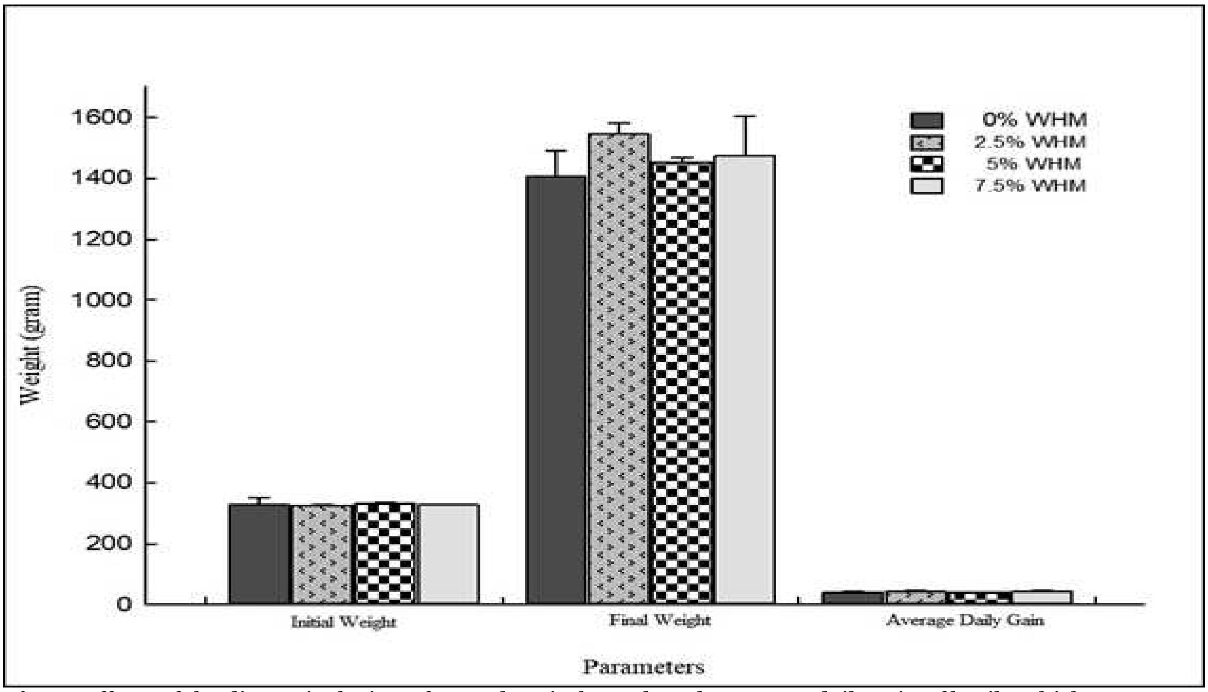

Fig. 1. Effects of the dietary inclusion of water hyacinth meal on the average daily gain of broiler chicken.

Return on investment

The inclusion of 2.5% of WHM into the diet increases the return above feed and chick cost up to 12.49PhP (USD 0.26) per bird. Thus, water hyacinth meal can be considered a valuable raw material vital to the feed milling industry to formulate balanced and quality feed for growing broilers at a lesser cost.

Conclusion

In light of the findings, the body weight gain showed higher value for birds fed with WHM diets than for those fed diets without WHM. Feed composition with 2.5% WHM in starter and finisher phases showed a sufficient amount for the higher final body weight and the rest of the growth performance parameters such as weight gain, feed intake, and feed conversion ratio. The broilers cell-mediated immunity response increased as the amount of WHM added to the diets was also increasing. There were no mortality data reported between all treatments. Therefore, a noxious water weed that needs a bundle of money and effort for its control and is available in any season all year round could be utilized as a feed resource in broiler production.

Author's contribution

The authors contributed equally to this manuscript.

Conflict of interest

The authors declare that there is no conflict of interest.

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