Feeding Value of Fermented Duckweed Meal (*Lemna minor* Linn.) as a Plant Protein Components in the Formulated Diets of Free-Range Chicken (*Gallus gallus domesticus* Linn.)

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***Abstract*—The present study evaluates the growth performance and hematological attribute of experimental free-range chicken, *Gallus gallus domesticus* Linn. (Black Australorp x Barred Plymouth Rock) fed formulated diets of fermented and non-fermented duckweed meal (*Lemna minor* Linn.). Three isonitrogenous formulated treatment diets are prepared: 0% duckweed (control), 10% Fermented Duckweed Meal (FDM), and 10% Duckweed Meal (DM) inclusions. Five chickens (mean weight = 202.5 g) per replicate are used in a three-month feeding trial under single factorial experiment. Chickens fed FDM diet have significantly (*P* < 0.05) higher mean final weight (1,182.8 ± 42.13 g) as compared to those fed DM diet (1,070.4 ± 84.61 g). The mean final weight of control and FDM is significantly homogenous (*P* > 0.05). Variation in feed conversion ratio among treatments is significant, with the highest mean value being observed in DM (5.85 ± 0.52). The average daily gain in weight is higher in DM and is comparable with the control (*P* > 0.05). Treatment diets have no significant effect on the observed hematological variables.**

***Keywords*—Bataan, FCR, feed formulation, food security, poultry, organic feed**

I. Introduction

Backyard free-range chickens precisely require stable sources of complete feed for optimum production and performance. To have a consistent and stable marketable weight, most growers use commercial feeds for feeding to complement the forage and free-range activities of the birds. However, the use of commercial feeds increases the cost of production, thereby, supplemental feeding is more economical [1].

The produce of native chicken like meat and eggs remained more suitable for popular Filipino dishes over the commercial broiler chicken because of its taste, leanness and color. However, with their limited supply, both meat and eggs are priced more than twice the commercial production. Similar to any domesticated poultry species, the highest cost of production comes from feeds, which accounts for about approximately 50 to 70%. The feed can go as high as 75% of the total cost of production in view of commercial feeds, being the major portion of the variable costs [2]. As the price of commercial feeds in the Philippines is constantly rising, it is imperative to explore alternative protein feedstuff for partial or full replacement to imported feed ingredients.

Duckweed species are small floating aquatic plants found worldwide and often seen growing in thick, blanket-like mats on still or slow moving, nutrient-rich fresh or brackish waters [3]. Often mistaken for algae, duckweed species are in fact monocotyledons of the botanical family Lemnaceae and are higher plants or macrophytes. Depending on the species, duckweeds grow at water temperatures between 6 and 33°C. Many species of duckweed cope with low temperatures by forming a turion, and the plant sinks to the bottom of a lagoon where it remains dormant until warmer water brings about a resumption of normal growth.

The present study investigated the efficacy of fermented and non-fermented duckweed meal as ingredients in the formulated diets for free-range chicken (Black Australorp x Barred Plymouth Rock). The study aimed to determine the growth performance of free-range chickens fed with corn-based formulated diets using 10% fermented duckweed meal and 10% non-fermented duckweed meal. The nutrient profile of treated feeds, feeding efficiency, and haematological parameters of experimental chickens were also analyzed.

II. Literature Review

A. Integrated Agri-Fisheries Farming System

The adoption of eco-friendly and community-based agri-fisheries production system has been one of the

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mandates in Central Luzon, Philippines to boost the farming productivity and profitability [4]. In response to this initiative, the BPSU have invested in the verification and demonstration trials of various integrated agri-fisheries technology projects [4–6]. Currently, researches are devoted to evaluate the efficacy of duckweed to replace commercial feed ingredients in the practical diets for various breeds of chicken and possibly to other livestocks.

B. Duckweed as a Plant-Based Protein Source

Duckweed is a small nitrogen-fixing aquatic plant and usually observed growing in thick, blanket-like mats on still or slow moving, nutrient-rich fresh or brackish water [3]. Studies have been suggested that duckweed species (*Lemna* spp.) are good sources of plant protein and have the potential to replace plant-based feed ingredients for improved growth performance of chickens [7–9]. Due to essential protein components and nutritional properties, duckweeds have been largely used as a supplemental feedstuff to animals and fishes [10, 11]. In fact, duckweed can be fed at a 12.6% inclusion rate and not impact the performance of laying hens and may be a means of enhancing Omega 3 levels in eggs [8]. It could partially replace costly sesame oil meal for the feed formulation of cost-effective broiler diet, likewise, the use at levels of 15% in the diets of broiler could be made [7, 9].

III. MATERIALS AND METHODS

A. Experimental Animal and Treatment Diets

From more than 150 acclimatized chickens, 75 free-range chickens (Black Australorp x Barred Plymouth Rock) were used in this feeding experiment. Gross evaluation of physical attributes prior to experiment were done. Disease and external parasites were not found. The 35-d old chickens were raised and acclimatized at the Poultry Experimental Facility in Bataan Peninsula State University (BPSU), Philippines.

Experimental feeds were produced using the local-based feed ingredients including rice bran, molasses, vegetable oil, oyster shells, salt, fish meal, soybean meal and yellow corn. The formulated diets were prepared following the details listed in Table I.

Locally produced duckweeds were harvested from freshwater concrete fishponds (2 m × 10 m × 0.6 m) of BPSU. Fresh duckweeds were first washed with clean water, drained and sun-dried for five (5) days and oven dried for 5 minutes until reaching at least 14% moisture content. The Fermented Duckweed Meal (FDM) was produced by fermenting through aerobic conditions using Effective Microorganism Activated Solutions and molasses for seven days. The fermented duckweeds were air-dried and oven-dried until the 14% moisture content was observed. For non-fermented Duckweed Meal (DM), duckweed samples were also oven dried for 15 min to attain the 14.0% moisture content.

The samples of the experimental diets were subjected to laboratory analyses to determine the proximate analysis, calcium, phosphorus, salt, NFE, Metabolizable energy, mycotoxins and amino acids (lysine, methionine + cysteine and methionine) of feeds. The common feedstuffs in the locality such as rice bran D1, molasses, vegetable oil, oyster shells, salt, fish meal, soybean meal, yellow corn and duckweed meal were used. The formulated feeds containing 16.0% crude protein and about 2,800 ME/kcal/kg were achieved and standardized among treatment groups. No additives and supplements were added in the feed formulation. The experimental feeds were fed in pelletized form. Proximate composition and nutrient composition of formulated feeds are detailed in Table I.

TABLE I. FEED FORMULATION AND CALCULATED ANALYSIS OF THE TREATED DIETS

Feed Ingredients	Control	FDM	DM
yellow corn, %	47.21	42.5	46
fish meal, 50%	7.0	5.0	5.76
molasses, g	3.0	0.25	3.0
rice bran D1, g	25	24	19.09
soybean meal (Full Fat), g	14.54	15	12.8
duckweed, g	0	10	10
limestone, g	1.0	1.0	1.0
coconut oil, g	2.0	2.0	2.0
salt, g	0.25	0.25	0.25
Total	100	100	100
Calculated Analysis			
ME (kcal/kg)	2,827	2,870	2,820
Crude Protein, %	15.93	15.91	15.99
Fat, %	8.0	7.6	7.0
Fiber, %	4.18	4.94	4.8
Ash, %	5.00	5.81	6.8
Calcium, %	1.0	1.0	1.0
Avail Phosphorus, %	0.37	0.31	0.4
Lysine, %	0.37	1.27	1.2
Methionine, %	0.64	0.42	0.41
Met + Cystine, %	0.64	0.86	0.828
Sodium chloride, %	0.94	0.12	0.9

Control: no duckweed; FDM: 10% fermented duckweed meal; DM: 10% non-fermented duckweed meal
Chemical and nutritional composition of the dry duckweed samples was determined according to standard AOAC methods

B. Experimental Design and Feeding Trial

Single factor experiment under completely randomized design with three dietary treatments and 25 chickens each treatment was employed. The experimental treatments were control-formulated feed without duckweed meal; FDM-10% fermented duckweed meal of corn-based diet and; DM-10% non-fermented duckweed meal of corn-based diet.

The study was conducted from February 2022 until June 2022 at the Poultry Experimental Facility in BPSU with a floor space of 2.0 ft² per bird in a full litter system. The chickens were fed twice a day with pre-weighed ration throughout the experiment. Sampling was done every month.

C. Production Parameters

For every month, the mean weight (g) of experimental chickens was determined using a digital balance (0.01 g), whereas daily gain in weight (%), gained in weight (g), final mean weight (g), daily gain (%), average mean consumption of treated feeds, Feed Conversion Ratio (FCR) = (feed consumed / gain in weight), and mortality were also determined.

D. Blood Collection and Hematological Measurements

At 100 days of age, blood samples (1 ml) were taken from two (2) chickens of each replicate. The hematological parameters were analyzed using Automatic Fully Digital Hematological Analyzer, BC 3000 Plus, Shenzhenb Minday, and Bio-Medical Electronics Co. LTD. These include erythrocytes, leukocytes, lymphocytes, granulocyte, MID (other types of leukocytes not classified as lymphocytes or granulocytes), hemoglobin, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and hematocrit.

E. Statistical Analyses

Growth performance, FCR, and hematological variables of treatments (mean ± SD) were compared using analysis of variance ($P < 0.05$). All data were normality as indicated by Shapiro-wilk test ($P < 0.05$). Tukey's post-hoc test was then employed to determine the significant variation between treatment means ($P < 0.05$). Parameters were expressed as means ± standard deviation. Statistical analyses were performed using a statistical package software, Statistical Tool for Agriculture Research.

IV. Results and Discussions

The summarized data in growth parameters and FCR of experimental chicken is presented in Table II. Changes in mean weight of chicken fed with formulated diets are illustrated in Fig. 1. The mean final weight of FDM and DM was significantly different ($P < 0.05$), whilst the control and FDM was statistically homogenous ($P > 0.05$). The FCR of control is significantly lower than DM, albeit it was comparable to FDM. Similarly, the Average Daily GAIN (ADG) was found to be significant ($P < 0.05$) from birds fed diets containing 10% fermented duckweed meal and control ration. The experimental birds of the treated groups consumed ($P < 0.05$) more feeds than the control.

The observed variation can be attributed to a better array of essential amino acids of duckweed than most vegetable proteins, and it closely resembles animal protein [9, 11, 12]. The performance of chickens was affected by iso-energetic formulated diets containing duckweed meal, which has its effect on live weight, feed conversion and profitability. However, several studies [13, 14] observed that layer feeds containing duckweed meal as feed ingredient had no impact on overall performance of chicken layers. The present result indicates birds fed diets containing duckweed meal have better appetite as compared with the diet without duckweed meal, albeit the feeding efficiency data otherwise.

The work of Rusoff and colleague [15] verified that the amino acid profile of the protein concentrate of duckweeds could be used as an effective protein supplement in diets low in lysine including rice and corn diet-based. Moreover, duckweed has crude protein level ranged from 26.3 to 45.5% of plant dry mass. The amino acid content of the plant compared favorably with that of blood, soybean and cottonseed meals which considerably exceeded that of groundnut meal [16].

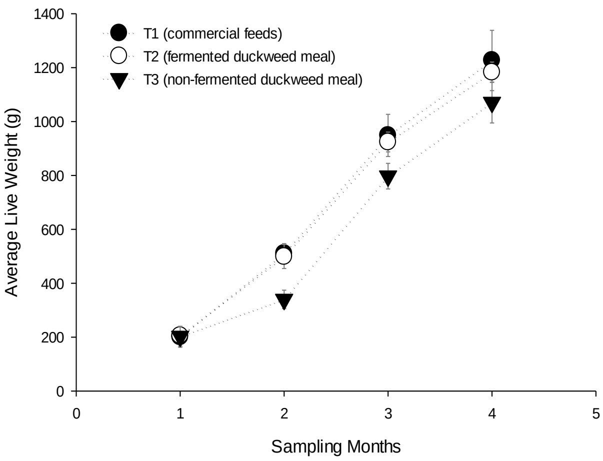

Figure 1. Changes in the mean live body weight of free-range chicken, *Gallus gallus domesticus* fed formulated diets with duckweed meal. Vertical error bars = SD.

TABLE II. Growth and Feeding Performance (Mean ± SD) of Experimental Free-Range Chicken (*Gallus gallus domesticus*) Fed Diets with Duckweed Meal

Growth and Feeding Performance	Control	FDM	DM	*F* value
Initial weight (g)	200.20 ± 32.70 ^{a}	203.25 ± 28.37 ^{a}	202.5 ± 25.00 ^{a}	0.10^{NS}
Final Weight (g)	1,226.4 ± 125.19 ^{a}	1,182.8 ± 42.13 ^{a}	1,070.4 ± 84.61^{b}	3.95*
Daily Gain (%)	13.33 ± 1.62 ^{a}	12.76 ± 0.54^{a}	11.30 ± 1.09 ^{b}	3.95*
Average Feed Consumption (g)	4,878 ± 124.36^{b}	5,153 ± 141.49^{a}	5,062 ± 145.26^{ab}	5.20*
Feed Conversion Ratio	4.79 ± 0.48^{b}	5.25 ± 0.23^{ab}	5.85 ± 0.52^{a}	7.59**

Control: no duckweed; FDM: 10% fermented duckweed meal; DM: 10% non-fermented duckweed meal

In a row, means with different superscript letter are significantly different ($P < 0.05$). $a > b$. ^{NS} not significant at 5% level of confidence; *significant at 5% level of confidence; **significant at 1% level of confidence

As reflected in Table III, the hematological values of the birds did not show significant variation. The results indicate that the health condition of the experimental chickens was not affected by treated diets, either containing fermented or non-fermented duckweed. It is viewed that the experimental ration performed equally in-terms of heath attributes of the birds. In fact, no manifestation of morbidity and mortality were recorded during the feeding period. The results are in accordance with the previous studies that no significant difference was found on blood analyses of birds fed with the treated diets [17]. The hematological parameters were lower than the normal numeric values in each blood test. Therefore, hematological disorders were not observed among its variables. The numeric difference between the results, and the normal hematological values confirms the efficiency of the feeds formulated solely out of the feedstuffs with no added supplements and additives.

TABLE III. HEMATOLOGICAL PARAMETERS (MEAN ± SD) OF FREE-RANGE CHICKEN, *Gallus gallus domesticus* DIETS WITH DUCKWEED MEAL

Hematological Variables	**Control**	**FDM**	**DM**	***F* value**
Erythrocyte (10^6 /mm^3)	2.65 ± 0.29	2.87 ± 0.31	2.83 ± 0.36	0.08^{NS}
Leukocyte (10^3 / mm^3)	28.74 ± 6.22	27.88 ± 7.54	26.80 ± 9.31	0.06^{NS}
Lymphocyte %	85.68 ± 2.29	84.18 ± 2.45	85.48 ± 3.83	0.38^{NS}
Granulocyte %	7.14 ± 1.34	8.42 ± 1.70	7.80 ± 2.43	0.58^{NS}
MID %	7.18 ± 0.97	7.40 ± 1.12	6.72 ± 1.63	0.37^{NS}
Hb, g dL^{-1}	9.74 ± 12.54	9.44 ± 15.99	9.77 ± 14.77	0.07^{NS}
MCV, fL	101.66 ± 1.91	100.82 ± 2.29	100.8 ± 2.14	0.27^{NS}
MCH, %	44.36 ± 3.12	40.98 ± 0.99	42.76 ± 2.33	2.66^{NS}
MCHC, g mL^{-1}	43.7 ± 2.71	40.81 ± 1.61	43.63 ± 2.36	2.49^{NS}
Hematocrit, %	29.56 ± 3.69	27.72 ± 3.64	29.30 ± 3.78	0.36^{NS}

Control: no duckweed; FDM: 10% fermented duckweed meal; DM: 10% non-fermented duckweed meal
MID: other types of leukocytes not classified as lymphocytes or granulocytes; Hb: hemoglobin; MCV: mean corpuscular volume; MCH: Mean Corpuscular Hemoglobin; MCHC: Mean Corpuscular Hemoglobin Concentration

V. CONCLUSION AND RECOMMENDATIONS

The present findings demonstrated that fermented duckweed meal-based formulated diet had a potential to replace commercial ingredients (e.g., soybean meal and fishmeal) in poultry feed for free-range chickens. In this way, the duckweed-based practical diet may cut the production cost, and thus improve the profitability for this type of business enterprise.

Further investigation can be pursued using other duckweed species, elucidating the efficacy of diet on reproductive performance, nutritional attribute, and sensorial quality in other Philippine native chicken breeds.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Hermogenes M. Paguia, Jesus Rex A. Pinsel, Rina Q. Paguia Steve D. Zabala wrote the draft of paper for publication and conducted the feeding experiment; Abigail G. Abuan, and Gregorio J. Rodis: revision of manuscript based on the comments of reviewers; all authors had approved the final version.

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