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Research article

Hematology, Blood Serum, Growth Performance, and Carcass Characteristics of Slow-growing Chickens Fed Single and Blended Root Meals

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Abstract

Toxins and substances with anti-nutritional potential have impeded the successful integration of root and tuber crops into animal diets. However, the ultimate indices of the physiological state of a farm animal are the growth performance and blood profiles. Hence, single and mixed formulations of *Dioscorea hispida* and *Cyrtosperma merkusii* root meals were used to assess chicken performance and hematological reactions. Two hundred and forty Bisaya chickens were fed with maize and root meals. Each set of treatments had 60 chickens, with three replicates of 20. The diets were: T1 (100% corn-based), T2 (50% *D. hispida* diet), T3 (50% *C. merkusii* diet), and T4 (25% *D. hispida*+25% *C. merkusii* diet). Feed intake, body weight, and mean weight gain (MWG) were collected biweekly, and carcass evaluation was done on harvesting. Hematological indices and serum profiles were tested. The T1 and T4 diets produced the most significant body weight and MWG, followed by T2 and T3. An improved feed conversion ratio (FCR) for T1 and T4 were significantly different from T2 and T3. The T4 specific growth rate (SGR) was similar to T1 and T2 but greater than T3. The T1 diet gave the most significant slaughter weight and dress weight, carcass components, and edible offal, followed by T4. The T4 diet raised PCV, RBC, Hb, cholesterol, and triglycerides more than T2, and T3, but no significant difference was found between T4 and T1. All solo root meal substitutes (T2 and T3) negatively impacted chicken performance; however, the 25% *D. hispida*+25% *C. merkusii* mix (T4) enhanced growth performance, most carcass features, and the blood profiles of slow-growing chickens when compared to a corn-based diet (T1).

Keywords

alternative energy source;
Cyrtosperma merkusii;
Dioscoreae hispida;
intensive system;
isocaloric;
isonitrogenous;
native chicken

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1. Introduction

The successful development of animal diets by replacing maize with root crops has attracted considerable interest. This is probably because root crop-based diets offer potential economic benefits by reducing feed costs, and utilizing materials that are locally available. The formulation of a root crop-based diet is usually obtained by decreasing the maize inclusions and increasing the inclusion of root crops meal associated with other essential feed components, additives, and supplements. However, an alternative approach was implemented in the present study where maize was replaced partially by a sole and combined use of *Dioscorea hispida* and *Cyrtosperma merkusii* root crop meals. The replacement level of maize was 50:50 (wt./wt.) basis of total maize constituents from corn soya-based diets, and other ingredients were adjusted accordingly to achieve an isocaloric and isonitrogenous (the same amount of energy and protein, respectively) diets. The rationale behind this approach was that the combined root meals could elevate the concentration of different nutrients compared to any single root inclusion. It was considered that differences in nutritional composition could influence chicken performance and physiological responses.

Wild yam (*Dioscorea hispida* Dennst) is a poisonous yam [1] belonging to the genus Dioscorea L. (family Dioscoreaceae), which is consumed as food during famine and used as a medicine by indigenous peoples in Southeast Asia. Detoxification by washing, cooking, drying, and soaking the tuber starches with NaCl solutions can reduce cyanide content in wild yam [2-5]. High levels of animal diet inclusion of edible yams (*Dioscorea spp*.) produced no reported effects on the performance of broiler chickens [6-8], but the inclusion of the poisonous wild yam must be very minimal due to the toxins. The giant swamp taro (*Cyrtosperma merkusii*) grows profusely in swamps and on riverbanks, where they remain uncultivated, neglected, and possibly unknown for their economic benefits. A study with taro cocoyam [9] revealed it could effectively be used to replace maize at the 25% (raw sundried) and 50% (boiled sundried) levels with its functioning as a source of energy in the diets of the broilers. However, evidence on ultimate inclusion that resulted in a comparable result with commercial or corn-based diets was inconclusive. For example, 20% solid-state fermented taro tubers for growing pigs [10], 25% cocoyam-corms meal for finisher broilers [11], 40% taro tuberous meal for fattening pigs [12], and 30% cocoyam corms inclusion for finisher lambs [13] were reported. However, the ultimate indices of the physiological state of an animal are the growth performance and blood profiles [14-16]. Togun and Oseni [17] stated that hematological examination can determine diseases and monitor feed stress. Others observed that nutrition significantly affects PCV, Hb, RBC, and other hematological indices [18]. Conditions such as stress, bacterial and viral infections, and intoxications change the blood picture as the animal grows. Other workers concluded that red blood cells (RBC) and other parameters such as hemoglobin (Hb) and erythrocyte sedimentation rate (ESR) of a bird vary among species, and other factors which can affect blood counts, including breed, sex, and the nutrition supplied to the bird [14-16]. Since wild yam and giant swamp taro have different nutritional and anti-nutritional contents, their combination as a feed resource for chickens was expected to have a positive effect on the growth and other physiological indices. Based on searches on the Web of Science, we found only one research work that involved the study of the effect of root crop mixture as a source of dietary energy on broiler chickens [6]. The study of Diarra [6] utilized the peels of edible yams and sweet potatoes from root crop processing plants but not the roots of poisonous wild yams. Hence, our study is among the first to consider a mixture of the poisonous wild yam (*Dioscorea hispida*) and giant swamp taro (*Cyrtosperma merkusii*) as an energy source for native chickens.

Thus, the main objective of this investigation was to determine the impact of using the poisonous wild yam and giant swamp taro root meal (in a single or a combination method of replacing 50% part of maize) as energy sources on the growth performance, hematological profile, and carcass yield of slow-growing chickens.

2. Materials and Methods

2.1 Experimental site

The study complied with the rules and regulations on the scientific procedures of using animals under the Philippines Republic No. 8485, otherwise known as the "Animal Welfare Act of 1998", and ethical standards at Surigao State College of Technology, Surigao City, Philippines. The experiment was carried out at the Poultry Laboratory area of Surigao State Norte State University – Mainit Campus from January to April 2020. The College was about 4 km from Mainit's main town in Surigao del Norte, Philippines.

2.2 Study animal and experimental layout

Two hundred and forty heads of unsexed 30 days post-hatch "Bisaya" chickens (*Gallus gallus domesticus*), an indigenous breed of chickens in the Philippines sourced from the SSCT-Mainit College Native Chicken Production project, were utilized for the experiment. The chickens were randomly assigned to four experimental groups of 60 chickens, with three replications holding 20 chickens each. The chickens were offered four dietary treatments from 30 to 90 days post-hatch. Each diet contained a single or a combined 50% root meal inclusion according to their ascribed treatment.

T1 = 100% Corn-based diet (control)
T2 = 50% Corn + 50% *D. hispida* diet
T3 = 50% Corn + 50% *C. merkusii* diet
T4 = 50% Corn + 25% *D. hispida* + 25% *C. merkusii* diet

2.3 Management of experimental animals

Experimental chickens were housed in 2.00 m x 2.00 m wire net cages and floor pens and were spaced at a one-meter distance from the other cages. All chickens received an ad libitum dry grower mash feeding and watering, periodic health monitoring, and standard vaccinations analogous to broiler chicken production. Feed offered and feed refused were recorded daily.

2.4 Processing of root crops, maize grains, and diet formulation

Dioscorea hispida and *Cyrtosperma merkusii* were gathered from swamps and secondary forests of Mainit, Surigao del Norte. Tubers of *D. hispida* were cleaned, manually peeled, chopped finely to approximately 2 cm, and added to boiling water at a 1:1 (wt./vol) ratio for 2 h. The cooking water was emptied, followed by sun-drying for 5 days. Finally, the dried yam chips were hammer milled. *Cyrtosperma merkusii* corms were thoroughly washed with tap water, hand peeled, and chopped finely by hand. After this, the corm chips were sundried until the moisture content dropped to 12%. Maize (yellow) grains were purchased from local corn growers, sundried, and consequently ground to a grit size of 1.69 mm to 2.00 mm, which passed through US Sieve No. 10. Other feedstuffs and vitamin and mineral additives were purchased from agri-veterinary suppliers. Diets in treatments T2, T3, and T4 were formulated with replacement of maize with 50% *D. hispida*, and 50% *C. merkusii* and a blend of *D. hispida* + *C. merkusii* (1:1) ratio (Table 1). The replacement of maize was quantitatively (w/w) basis on the total weight of maize in a 100% corn-based diet treatment, while all other ingredients were adjusted to make the diets isocaloric and isonitrogenous (Figure 1). Grower diets were formulated to contain 17% CP, 2750 Kcal/kg M.E., 1% calcium, 0.68 lysine, 0.33 methionine, 0.58 met + cys, 0.55 threonine and 0.17 tryptophan. The experimental diet composition met the requirements of National Research Council [19]. Samples of experimental diets, i.e., the *D. hispida*, and *C. merkusii* meals, were submitted for analysis of proximate nutritional composition (Table 2).

Table 1. Gross composition of experimental grower diets (kg)

Ingredients	**T1**	**T2**	**T3**	**T4**
Giant swamp taro meal			29	14.5
Wild yam tuber meal		29		14.5
Hammered corn	58	29	29	29
Corn bran	13.5	13	10.5	13.5
Soybean meal	13	12	12	12
Fish meal	3	8	6	7
Copra meal	10.5	6.25	11	7.4
Coco oil	0.25	1	0.75	0.5
Molasses	0.5	0.5	0.5	0.5
Limestone	0.5	0.5	0.5	0.4
Salt	0.5	0.5	0.5	0.45
Vitamin premix*	0.25	0.25	0.25	0.25
Total	100	100	100	100
Calculated composition (% D.M.)				
C.P. (%)	17.03	17.03	17	17
ME (kcal/kg)	2754.05	2754.01	2754.02	2754.01
Ca	0.25	0.3	0.27	0.28
P	0.39	0.4	0.36	0.38
Met	0.28	0.24	0.29	0.28
Met & Sys	0.5	0.46	0.51	0.52
Lys	0.54	0.59	0.5	0.56
Threonine	0.48	0.44	0.45	0.49
Tryptophan	0.12	0.11	0.09	0.11

*Vitamin/mineral premix 500 g: Dicalcium phosphate 97%, vits. A 150,000 I.U., D3 30,000 I.U., E 500 I.U., potassium iodide 100 mg, manganese sulfate 3,500 mg, ferrous sulfate 3,500 mg, copper sulfate 1,500 mg, cobalt sulfate 1,500 mg, and zinc sulfate 200 mg
T1–corn-based, T2–50% *D. hispida*, T3–50% *C. merkusii*, T4–25% *D. hispida*+25% *C. merkusii*

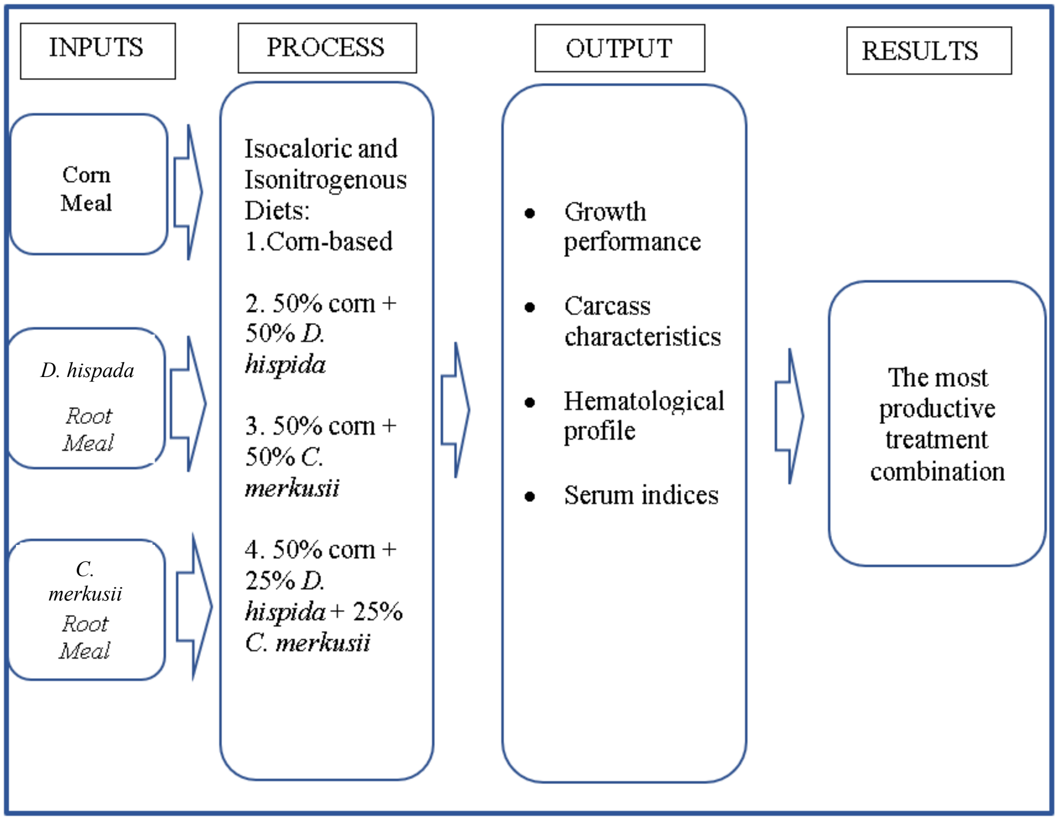

Figure 1. Experimental process flow

Table 2. Analyzed composition of experimental grower diets, *D. hispida* and *C. merkusii* meals

Parameters	T1	T2	T3	T4	*D. hispida*	*C. merkusii*
Moisture (%)	11.32	8.57	9.93	10.04	9.61	13.91
Ash (%)	4.3	4.37	5.13	3.85	9.37	4.82
Crude protein (%)	17.45	17.27	17.39	17.29	4.38	5.94
Crude fiber (%)	3.31	3.44	3.89	3.66	2.76	7.15
Crude fat (%)	3.10	2.92	1.81	2.90	0.24	0.06
Nitrogen-free extract (%)	60.52	63.43	62.85	63.26	63.44	68.2
Metabolizable energy (Kcal/Kg)	2800.67	2800.04	2801	2800.19	2304.29	2630.58

T1 – corn-based, T2–50% *D. hispida*, T3–50% *C. merkusii*, T4–25% *D. hispida*+25% *C. Merkusii*

2.5 Data collection

The initial weights were assessed after brooding for approximately 30 days post-hatch, while growth traits and feed intake were assessed bi-weekly: carcass traits and organ weights were evaluated at harvest. Two chickens of average body weight per replicate were selected, slaughtered, eviscerated, and assessed for dress weight and dressing percentage: the organ weights and carcass components were calculated according to percentage g/100 g B.W. Blood samples were collected during the 12th week of the feeding trial.

Three chickens of apparently healthy condition per cage were euthanized and 5 mL blood samples from the neck veins were collected with a 5 mL sterile syringe and a 23-gauge needle.

For the hematological determination, 2 mL blood samples were set aside and placed in a sterile tube with anti-coagulant ethylene diamine tetra-acetate (EDTA), while for serum analysis, 3 mL blood samples were kept in a separate sterile tube intended for the purpose.
Hematological indices such as hemoglobin concentration (Hb) were determined using Sahl's hemoglobinometer expressed in g/100 mL. Red blood cells (RBC) and white blood cells (WBC) were determined by the Neubauer hemocytometer method [20]. A standard manual technique measured the PCV (pack cell volume), while MCV (mean corpuscular volume), MCH (mean corpuscular hemoglobin), and MCHC (mean corpuscular hemoglobin concentration) were calculated from RBC, PCV, and Hb, respectively, using the following formulae:

MCV (%) = PVC x 10/RBC
MCH (%) = HB x 10/RBC
MCHC (%) = HB x 100/PVC

Serum enzyme activities of ALT, AST, ALP, and serum biochemical values of albumin, globulin, cholesterol, and total protein were measured using commercial kits and the spectrometer [21].

2.6 Statistical analysis

All experimental data were subjected to Shapiro-Wilk Test of normality to determine the normal distribution of data before the analyses of variance (ANOVA). A completely randomized design (CRD) was conducted using SPSS ver. 26 in the Windows package. Means were partitioned by the Tukey HSD test, with a significance level set at $P < 0.05$.

3. Results and Discussion

This study determined the effect of sole and blended *D. hispida* and *C. merkusii* meals as a replacement for maize on the performance and hematological profiles of *Bisaya* chickens at 50% levels. The data showed a depressed feed intake, final weight, mean weight gain, and specific growth rate of chickens fed T2 and T3 (Table 3). However, comparable performance results relative to T1 were observed when these two root crop meals were blended (25% *D. hispida* + 25% *C. merkusii*) together (T4) to replace 50% of maize. The result suggested the acceptability of the blended *D. hispida* + *C. merkusii* diet on par with the corn-based diet.

When compared with T2 and T3, chickens fed with T4 showed consistently better results. The result shows that the *D. hispida* + *C. merkusii* blend could be substituted for corn at up to 50% for a slow-growing chicken diet. The improved and better performance observed in T4 vs. T2 and

Table 3. Effects of diet on feed intake, final weight, mean weight gain, specific growth rate, feed conversion ratio (FCR), and mortality rate of chickens from 30-90 days post-hatch

Parameters	T1	T2	T3	T4	p-value
Feed Intake (g)	3985.94^{a}	3619.53^{d}	3771.24^{c}	3804.25^{b}	< 0.001*
Final weight (g)	1424.39^{a}	1253.31^{b}	1203.80^{c}	1392.27^{a}	< 0.001*
Mean weight gain (g)	1099.66^{a}	952.69^{b}	895.16^{c}	1045.81^{a}	< 0.001*
Specific growth rate (%)	19.63^{a}	17.14^{bc}	15.84^{c}	18.81^{ab}	0.008*
Feed conversion ratio	3.63^{c}	3.93^{b}	4.30^{a}	3.67^{cb}	0.013*
Mortality rate	2	0	0	0	

* Means of different superscripts in each row are significant at a 5% probability level.
T1–corn-based, T2–50% *D. hispida*, T3–50% *C. merkusii*, T4–25% *D. hispida+25% C. merkusii*

T3 can be attributed to the acceptability of this diet. Based on the analysis of nutrients, *C. merkusii* taro meal was a good source of crude protein, fiber, NFE, and M.E. but had lower ash and fat, whereas *D. hispida* root meal was high in ash and fat contents (Table 2). The mixture of *D. hispida* and *C. merkusii* (25%: 25% ratio) was then a diet well-balanced in nutrients and this probably explained the growth performance improvements of chickens under this diet. This was of interest because *D. hispida* and *C. merkusii* singly were able to replace corn as an alternative energy source. There is no literature on the feeding value of combining these two root crops with poultry. These results suggested further verifications in future studies. The lower and reduced feed intake of chickens fed T2 over the others is associated with the bitter taste observed in *D. hispida* meal, which may have limited the consumption of feed by chickens on this diet. Oyeyinka *et al*. [22] reported that alkaloids, oxalates, and saponins in *Dioscorea bulbifera* (potato yam) and *Dioscorea dumentorum* (bitter yam) were bitter and of reduced acceptability to animals.

The T3-fed chickens had the lowest statistical values for final weight (FW), mean weight gain (MWG), and specific growth rate (SGR) among the root meal replacements during the experiment. This may be attributable to the anti-nutritional elements of *C. merkusii*-containing diets, the higher the taro inclusion, the higher concentrations of anti-nutritional substances in the diet. Temesgen and Retta [23] reported that the anti-nutritional elements commonly found in other species of the Araceae family, and which are abundant in most parts of the plant, cause throat and mouth epithelium irritation, thus indirectly reducing digestibility. Also, the significant reduction in the performance of chickens on T3 may be due to ingredient separation associated with the dusty nature of the *C. merkusii* tuber meal observed in this experiment. This was evident from the observed specks of dust stuck on feeders during the T3 treatment. Chickens of all ages desire a coarser feed particle [24-26]. However, particle size preferences are believed to increase with age. The lower the FCR, the less feed the chicken uses for gaining higher body weight. The higher FCR for T3 indicated presence of anti-nutritional factors that limited dietary nutrient utilization [27]. Abdulrashid and Agwunobi [9] demonstrated that FCR increases linearly as the levels of cocoyam meal inclusion increase, thus indicating that the higher the level of cocoyam meal, the less the utilization of the diets.

The higher and better ($P<0.05$) slaughter and dress weight for T1 over the T2, T3, and T4 diets was due to the excellent growth performance revealed in Table 4. Conversely, the lowest slaughter and dress weights recorded in chickens fed root meal diets was probably due to significantly inferior live weights. The result indicated a positive correlation between slaughter and dress weights and chicken final body weight (Table 5). However, the much lower dressing % for T1 diets compared to root replacements was inversely correlated with the ultimate body weight of chickens (Table 5). Except for back weight, all carcass components and edible internal offal values of chickens in T1 were higher than those of root meal diets. Thus, heavier carcasses and edible offal positively correlate with slaughter weight (Table 6).

The dressing percentage range of 60.08-68.61% reported in this study was lower than 72.43-73.09% reported by Beckford and Bartlett [28], and 77.03-81.20% by Jiwuba *et al*. [29] for broiler chickens. The significant (P<0.05) breast weight, back, liver, and gizzard values of the current study agree with the findings of Abdulrashid and Agwunobi [9], Jiwuba *et al*. [29], and Onunkwo and George [30] for broiler chickens. No differences in back weight observed in this study aligned with the results reported by Jiwuba *et al*. [29] but contradicted with the results reported by Abdulrashid and Agwunobi [9] and Onunkwo and George [30] for broiler chickens. The responses of diverse study animals and the limited sample sizes likely contributed to the conflicting findings. This investigation used slow-growing chickens with a limited number of specimens (*n*=240), while earlier broiler chickens in published studies used substantially high numbers of study animals.

The blood parameter determination provided information on the poultry's health status and physiological changes. In this study, chickens fed T2 and T3 had lower RBC, PCV, and Hb values when compared to T1 (Table 7). The results indicated the presence of anti-nutrition factors present in the root crops *D. hispida* and *C. merkusii* that are associated with a high dietary density and cause feed stress. Lower hematological parameters were due to the harmful effects of the diets [31, 32].

Table 4. Effects of diet on slaughter weight, dress weight, dressing percentage, neck, breast, thigh, back, heart, gizzard, and liver weight of chickens

Parameters	T1	T2	T3	T4	p-value
Slaughter wt.	1397.33^a	1127.50^d	1155.83^c	1346.67^b	< 0.001*
Dress wt.	954.83^a	765.00^c	766.67^c	923.33^b	< 0.001*
Dressing %	61.22^b	67.62^a	66.30^a	68.61^a	0.020*
Neck	98.46^a	78.33^b	65.00^c	106.37^a	< 0.001*
Breast	394.30^a	312.50^c	291.67^d	372.13^b	< 0.001*
Thigh	309.56^a	246.66^b	237.50^b	297.73^b	< 0.001*
Back	198.56	149.17	145	154.28	0.066
Gizzard	8.47^a	5.72^b	6.45^b	6.48^b	0.001*
Heart	3.82^a	3.43^b	3.59^b	2.59^b	0.027*
Liver	24.76^a	20.81^b	23.51^a	20.95^b	0.004*

* Means of different superscripts in each row are significant at a 5% level of probability.
T1–corn-based, T2–50% *D. hispida*, T3–50% *C. merkusii*, T4–25% *D. hispida+25% C. merkusii*

Table 5. Correlation coefficients of slaughter weight, dress weight, and dressing percentage with the final body weight of chickens fed diets containing sole or blended root meals

	Final weight	Slaughter weight	Dress weight	Dress %
Final weight	1			
Slaughter weight	.946**	1		
Dress weight	.959**	.993**	1	
Dress %	-0.368	-0.437	-0.423	1

** Correlation is significant at the 0.01 level (2-tailed)

Table 6. Correlation coefficients of carcass (breast, thigh, neck, and back) weights and edible internal offal (gizzard, liver, and heart) weight with dress weight of chickens fed diets containing sole or blended root meals

	Slaughter weight	Neck	Breast	Thigh	Back	Gizzard	Heart	Liver
Slaughter weight	1							
Neck	.835**	1						
Breast	.951**	.898**	1					
Thigh	.967**	.866**	.965**	1				
Back	.717**	0.475	.782**	.723**	1			
Gizzard	.733**	0.386	.692*	.663*	.859**	1		
Heart	-0.148	-0.389	-0.146	-0.180	0.337	0.459	1	
Liver	0.336	-0.105	0.193	0.230	0.518	.584*	0.482	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

Table 7. Effect of diets on hematological profile of chickens with literature values and normal hematological ranges value of chickens

Parameters	T1	T2	T3	T4	Literature	Normal Range#
PCV (%) *	46.35^{a}	38.41^{b}	39.60^{ab}	40.41^{ab}	29.50 - 35.50[1]	22.00 - 35.00
RBC ($x10^{12}$/L) *	3.38^{a}	2.14^{b}	2.16^{b}	3.00^{a}	2.77 - 3.47[1]	2.50 - 3.50
WBC (x 10^{9}/L)	19.11	19.14	18.46	18.64	15.27 - 16.47[1]	12.00 - 30.00
Hb (g/dL) *	13.32^{a}	9.92^{b}	10.01^{b}	12.01^{ab}	7.60 - 9.50[1]	7.00 - 13.00
MCV (fl)	83.9	83.01	84.61	84.11	99.35 -119.45[2]	90.00 -140.00
MCH (pg)	29.68	28.89	29.74	30.01	27.54 - 29.71[2]	33.00-47.00
MCHC (%)	46.26	46.98	46.66	47.03	26.86 - 29.29[2]	26.00 -35.00

*Means of different superscripts in each row are significant at a 5% level of probability.
PCV = Pack cell volume, RBC = Red blood cell, WBC = White blood cell, Hb = Hemoglobin, MCV = Mean corpuscular volume, MCH = Mean corpuscular hemoglobin, MCHC = Mean corpuscular hemoglobin concentration, g/dl = grams per deciliter, fl = femtoliter, pg = pectogram
T1 – corn-based, T2 – 50% *D. hispida*, T3 – 50% *C. merkusii,* T4 – 25% *D. hispida* + 25% *C. merkusii*
[1]Source: Diarra *et al*. [6], [2] Source: Jiwuba *et al*. [29], [#]Source: Bounous and Stedman [33]

Dioscorea hispida contains the alkaloid dioscorine and cyanogenic glycosides, which are toxic when consumed raw or improperly processed [1, 34, 35]. *Cyrtosperma merkusii* taro contained phytate, oxalate, tannin, saponin, and hydrocyanide [9]. However, T4 interestingly had an improved value for PCV, RBC, and Hb compared to the counterparts, 50% solo root replacements, indicating that the combination of the two root crops supported PCV, RBC, and Hb synthesis. Pack cell volume (PCV) and hemoglobin (Hb) are strong indicators of the nutritional status of animals [21]. Hematological values that fall within the normal range showed no adverse effect of diet on hematological parameters, but anemia is indicated when the values are lower than the normal range. The RBC values of chickens feeding T4 were higher than chickens fed on T2 and T3 diets and were within the normal range from the literature and the normal range for chickens (Table 7).

The homogenous WBC, MCH, MCB, and MCHC results among treatment diets concerning T1 in this trial suggest that the immune systems of chickens were not challenged by the feeding 50% sole or blending methods of root meal replacement (Table 8). The WBCs aid in protecting the body from pathogens, and carotenoids build up immunity [36, 37]. White blood cells, neutrophils, and lymphocytes fall within the normal range, signifying a normal immune response despite feeding patterns [38, 39]. Overall, some results of the current hematological profile in this study corroborated the literature and normal ranges for chickens, while others were either lower or higher. The complex animals used diet types likely contributed to the discrepancies in the result as breed, sex, and the nutrition supplied to the chickens affect hematological counts [13, 40].

Table 8. Effects of diet on serum biological indices of chickens with literature values and average hematological ranges value of chickens

Parameters	T1	T2	T3	T4	Literature Value[1]	Normal Range
Albumin (g/dL)	3.32	3.20	3.26	3.23	3.3 - 3.46	4.38-5.37[3]
Globulin (g/dL)	1.60	1.75	1.56	1.67	3.93 - 3.95	-
Total protein (gluten)	5.08	5.11	4.98	5.06	7.21 - 7.41	5.26-5.87[3]
AST (u/L)*	32.95^{ab}	32.38^{b}	33.14^{ab}	33.92^{a}	-	8.80-20.80[2]
ALT (u/L)	65.00	66.17	65.11	65.34	-	2.30-3.30[2]
ALP (u/L)	70.38	71.90	71.25	70.56	-	125-200[2]
Cholesterol (mg/dL)*	138.90^{a}	110.71^{b}	108.11^{b}	94.911^{c}	190.27 - 191.99	122-132[3]
Triglyceride (mg/dl) *	74.34^{a}	61.83^{b}	56.25^{c}	52.36^{c}	148.34 - 148.72	-

*Means of different superscripts in each row are significant at a 5% level of probability.
AST = Aspartate aminotransferase, ALT = Alanine aminotransferase, ALP = Alkaline phosphatase Glu = Glutamine synthetase, u/L = Units/Liter, mg/dL = Milligrams/deciliter
T1 – corn-based, T2 – 50% *D. hispida,* T3 – 50% *C. merkusii*, T4 – 25% *D. hispida* + 25% *C. merkusii*
[1] Source: Nguyen *et al.* [41], [2] Source: Makama *et al.* [42], [3] Olawumi *et al.* [43]

The cholesterol concentration of the chickens fed diets T2, T3, and T4 was significantly lower than the values recorded for T1. However, these values fall within normal range for chickens but are markedly lower than in the literature. Cholesterol is synthesized from fats and endogenously synthesized within the cells. A high level of cholesterol denotes a higher risk of cardiovascular problems. Triglycerides are synthesized in the liver from fatty acids, protein, and glucose, and when they are above the body's current needs, they are stored in adipose tissue [44]. Like cholesterol, the triglycerides were higher for T1, followed by T2, T3, and T4, which coincided with the normal range for chickens but was substantially lower than the values reported in the literature (see Table 8). According to Etuk *et al.* [45] and Odunitan-Wayas *et al*. [37], serum biochemical constituents are positively correlated with the quality of the diet.

4. Conclusions

Chickens fed diets consisting of either 50% *D. hispida* or 50% *C. merkusii* taro in place of maize had poorer development performance and altered hematological profiles compared to those fed diets containing a mix of the two. The final weight, mean weight gain, certain carcass components for dressing percentage and neck weights were enhanced, and the synthesis of RBC, PCV and Hb was supported by the 25% *D. hispida* and 25% *C. merkusii* root combination used as an alternative energy source for Bisaya chicken diets, which was on par with a 100% corn-based diet. However, the findings of this study were not definitive, and need to be confirmed in future research.

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