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Effect of Dietary Supplementation of Black Pepper (*Piper nigrum*) on the Performance and Health of Vanaraja Birds

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The investigation of Vanaraja birds on a diet supplemented with black pepper *(Piper nigrum)* powder" was carried out to study the productive performance, carcass traits, mortality, performance index, blood parameters, and economics of vanaraja birds. A total of one hundred and fifty (150) day-old vanaraja chicks were randomly divided into five treatment groups of thirty birds each, namely T_1 (control), T_2, T_3, T_4, and T_5, with 5 replications per treatment having 6 birds in each replicate following a randomized block design. Standard broiler diet (0–28) days and finisher ration (29–63 days) were provided to the birds. Black pepper powder was supplemented at the rates of 0, 0.25, 0.5, 0.75, and 1 g/kg feed in T_1, T_2, T_3, T_4, and T_5, respectively. Body weight, weight gain, and

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feed conversion efficiency were recorded on a weekly basis, while feed intake was noted on a daily basis. 5 birds from each treatment were killed on the 63rd day in order to evaluate the carcass, and 5 birds from each treatment were selected for collecting blood samples for hematological and biochemical blood analysis. Black pepper supplementation at 0.25 g/kg of basal diet resulted in significantly ($P<0.05$) higher body weight. Feed intake was significantly ($P<0.05$) higher in T_2 (black pepper @ 0.25%). The dressing and liver weight were better in the T2 group. The performance index was better in the T3 group. Also, blood constituents of cholesterol, HDL, LDL, and triglycerides were found to be lower in T_2 groups. The net profit per kg live weight of vanaraja was highest in T_1 compared to treatment groups. Based on the above findings, dietary supplementation of black pepper powder at the rate of 0.25 g/kg feed can be recommended under the agro-climatic condition of Nagaland.

Keywords: Vanaraja bird; black pepper powder; blood constituents; net profit.

1. INTRODUCTION

In India, total poultry production is 851.81 million, and it increases at the rate of 16.81% during the Livestock Census 2019. In India, backyard poultry population is 317.07 million, and commercial poultry population is 534.74 million. Overall, 45.78% increase in backyard poultry and commercial poultry has increased 4.5% in India. Tamil Nadu had the highest poultry population in India. The vanaraja bird, or officially (*Gallus gallus domesticus*), is an important poultry farming animal because of its distinctive genetic makeup and contributions to sustainable farming. The vanaraja is a hybrid of native Indian breeds that have been carefully cultivated to perform better under different climates and to be more tolerant of regional farming methods. The origins of this breed can be traced to attempts made in the middle of the 20th century to improve native chicken breeds in India. The main goals of the breeding program were to improve features like overall adaptability to rural farming situations, disease resistance, egg production, and meat quality.

Vanaraja birds are distinguished genetically by a varied lineage that combines features from native Indian breeds with contemporary breeding methods, leading to variations in plumage color, body size, and egg-laying capacity. Their genetic variety facilitates their adaptability to various management techniques and durability, making them suitable for a wide range of agricultural systems. The socioeconomic circumstances in rural communities are improved since they are affordable and require little upkeep, making them available to farmers with little resources.

Patel et al. (2018) explained that vanaraja is a dual-purpose multi-colored bird for poultry production. The color and feather pattern of vanaraja closely match that of jungle fowl, which is raised in backyards in communities and tribal habitations. Some spices and herbs, including turmeric, hot red pepper, ashwagandha, cinnamon, oregano, garlic, rosemary, and ginger, are the well-investigated phytobiotics in the diet of vanaraja. (Kostadinovic and Levic, 2012), (Puvaca et al. 2013).

Black pepper (*Piper nigrum*) is also known as 'king of spices, 'and 'black gold' is native to India within the family Piperaceae, genus Piper, and species nigrum. This woody perennial vine clings to trees, trellises, and other structures. Black pepper's main ingredient, piperin, is what gives it its pungent and stinging properties. Three categories of chemicals can be found in black pepper (*Piper nigrum*). The components in the first group determine how sharp black pepper is; the compounds in the second group determine how fragrant black pepper is; and the compounds in the third group include fiber, starch, polyphenols, mineral salts, and lipids, among other compounds. (Aleksandra et al., 2021).

Black pepper is medicinally used medicinally for a variety of conditions, such as antibacterial, antifungal, antiapoptotic, antidepressant, antidiarrheal, anti-inflammatory, antimutagenic, antioxidative, antipyretic, antispasmodic, antitumor, enhancing appetite and digestive function, treating dyspnea, colds, coughs, throat infections, treating intermittent fever, treating colic, treating dysentery, and getting rid of worms and piles. (Ahmad et al., 2012), (Islam et al., 2015). Glutathione peroxidase and glucose-6-phosphate dehydrogenase have been demonstrated to be abundant in black pepper (Karthikeyan and Rani, 2003).

"Piperine, the active ingredient of black pepper, increases absorption of serum, vitamin B, beta-

carotene, and other nutrients, favorably stimulating the digestive enzymes of the pancreas, enhancing the digestive capacity, and significantly reducing the gastrointestinal food transit time" (Srinivasan, 2007). "Black pepper is also used for culinary as well as medicinal purposes around the world. It increases digestion through digestive enzymes of the stomach and eradication of infectious bacteria" (Hosseini, 2011). Toghyani et al. (2010) explained that "piperine had biomolecular functions similar to various compounds, including vitamin K, to reduce the use of phytogenic substances presenting active biomolecular compounds with similar functions to synthetic compounds. They have the potential to boost poultry production by assisting in the control of certain metabolic processes".

According to Moorthy et al. (2009), piperine affects the neurological system, aiding in digestion and boosting the body's absorption of minerals including beta-carotene, vitamin complex, and selenium. Feed additives serve as catalysts in the digestion and metabolism of nutrients. It also improves digestibility (Acker, 1983). Piperine has an antiache effect (Mahady et al., 2008). The bioactive compound in pepper aids in digestion and has a significant pharmacological effect on neurons and the neuromuscular system (Great, 2003). Being a natural commodity, black pepper may be produced at a minimal cost and in large numbers.

2. MATERIALS AND METHODS

2.1 Location of the Study

The research was conducted at Nagaland University's Instructional Livestock Farm, Department of Livestock Production and Management, School of Agricultural Sciences, Medziphema Campus, Nagaland. The farm's coordinates are 93.20º E to 95.15º longitude, 25.6º N latitude, and a height of 310 meters above sea level (MSL).

2.2 Materials

A total of 150 commercial vanaraja chicks from a single hatch were obtained from the ICAR Medziphema, Nagaland. When the birds arrived, they were individually weighed and randomly assigned to one of the dietary treatment groups, with 30 birds in each group. The dietary treatments comprised feeding a basal diet as a control, while the other treatment groups were fed varied quantities of black pepper powder at rates of 0.25, 0.5, 0.75, and 1 g per kg of feed. Vanaraja chicks were fed a normal diet. The feeding was divided into two phases: normal starter ration (0–28 days) and finisher ration (29–63 days). The standard ration was obtained from a reputed commercial feed manufacturer in Dimapur, Nagaland. A precise amount of black pepper at 0.25, 0.5, 0.75, and 1 g/kg feed was added and held in separate bags as T_1 (control) and T_2, T_3, T_4, and T_5 as treatment groups, respectively. To guarantee *ad libitum* feeding, the chicks received a weighed amount of feed from each treatment group on a daily basis. The birds were provided with fresh and clean water throughout the trial. The birds were nurtured in a deep litter system during the brooding period, and subsequently, on the fifth week, they were transferred to cages. Black pepper powder was obtained from the Dimapur new market in Nagaland. The purchased black pepper was pounded into powder using an industrial blender and then kept in airtight containers until required.

2.3 Treatment and Feeding

Completely Randomized Block Design (CRD) was followed in the execution of the experiment described by (Snedecor and Cochran 1994). A total of 150 chicks were randomly assigned to five (5) distinct groups (referred to as T_1, T_2, T_3, T_4, and T_5), with each group consisting of thirty (30) chicks that each had five replicates of six (6) birds. The chicks were raised in deep litter systems until they were 28 days old, after which they spent 35 days in cages in the finisher house. Standard starter was fed to the chicks from 1-4 weeks of age, while finisher was provided from 5-9 weeks of age. The basal diet was given to Group 1 (T_1), which was the control group. The chicks in the other five treatment groups were also provided with the same basal diet as in T_1 but supplemented with different levels of black pepper powder. The details of the distribution of chicks and their treatment are summarized in Table 1.

The body weights of chicks were taken on the first day of arrival. Thereafter, on a weekly basis, the average body weight was taken in the morning prior to feeding and watering. A digital weighing balance having a maximum capacity of 10 kg was used for the entire experiment for weighing the birds. During the first four weeks, the average weight of the chicks was recorded in groups. This was done by placing 5–10 chicks each in a pre-weighed carton box. From 5th weeks onwards, the birds were weighed

Table 1. Details of the distribution of chicks and their treatment

Group	Total no. of Birds	Quantity of Black Pepper to Basal Diet
T1 (control)	30	Basal diet
T2	30	Basal diet + 0.25g black pepper /kg feed
T3	30	Basal diet + 0.5g black pepper /kg feed
T4	30	Basal diet + 0.75g black pepper /kg feed
T5	30	Basal diet + 1g black pepper /kg feed

individually at weekly intervals till they attained nine weeks of age, i.e., 63 days of age. This information was used to determine the average daily and weekly feed intake, reported in grams, for each bird in each group. The formula below was utilized to calculate the feed conversion efficiency (FCE) of the various experiments. At the end of the feeding trial, two birds were randomly selected from each treatment for the blood collection. The blood was collected from the wing veins of the birds by sterilizing and rubbing an area with disinfectant and cotton wool and then collecting about 2 ml of blood with the use of sterile needles into well-labeled, heparinized sterilized tubes. Samples were used for measurement of various blood parameters, including HDL, LDL, cholesterol, and triglyceride, and the sample to be used for measurement of WBC, RBC, hemoglobin (Hb), and PCV was collected in a sterilized tube containing Heparin as an anticoagulant. Mortality was recorded daily during the period of investigation and was expressed in percentage. Mortality was calculated by using the following formula: The liveability percentage was calculated by subtracting the mortality percentage from 100. Performance index (PI) was calculated by adopting the formula of Bird (1955). Following the trial, three birds were chosen at random for carcass evaluation studies from each group. Prior to slaughter, the live weight of each individual bird was noted. Using the Standard Method, slaughtering was carried out. After the bird was completely bled and its feathers removed, its dressed weight was determined. The average weight of the heart, liver, spleen, and (empty) gizzard was noted for each of the five groups. These organs were also weighed separately. The following calculation was used to get the percentage of dressed weight.

3. RESULTS AND DISCUSSION

3.1 Body Weight

The average body weights of day old chicks for T_1, T_2, T_3, T_4, and T_5 groups were 31.66, 31.40, 30.40, 32.20, and 32.20 g per bird, respectively. The corresponding body weight for the various treatment groups was 1695.20, 1738.20, 1719.60, 1717.60, and 1714.20 g per bird at the end of the ninth week. The overall mean of the body weight was 800.54, 830.43, 816.63, 822.80, and 822.54 g/bird/week for T_1, T_2, T_3, T_4, and T_5 groups, respectively. From the statistical analysis, it had been revealed that supplementation with black pepper had a significant effect on the final body weight. The treatment group T_2 had significantly ($P<0.05$) higher body weight, followed by T_3, T_4, and T_5 the least in the control group. However, the difference among T_3, T_4, and T_5 was found to be non-significant. The results of the present study were well corroborated with the findings of Al-Kassie et al. (2011), Zuyie et al (2011), Tazi et al. (2014), and Aikpitanyi et al. (2019), who had also reported significantly higher body weight due to supplementation of black pepper as compared to the control group. Higher body weight in the black pepper supplemented group might be due to the presence of piperine, the active ingredient of black pepper, which caused increased absorption of serum, vitamin B, beta-carotene, and other nutrients, favorably stimulating the digestive enzymes of the pancreas, enhancing the digestive capacity, and significantly reducing the gastrointestinal food transit time (Srinivasan 2007). In addition, it may be due to increased enzymes in the stomach and the eradication of infectious bacteria (Hosseini, 2011).

3.2 Gain in Body Weight

From Table 2, it was observed that average weight gain during the first week for Vanaraja birds was 49.97, 48.95, 53.88, 53.97, and 48.10 g per bird for T_1, T_2, T_3, T_4, and T_5 groups, respectively. The corresponding weight gain of the birds on the 9^{th} week of age was 255.80, 247.20, 253.20, 251.20, and 243.80 g/bird. From the perusal of the data, the values for gain in weight were significantly higher ($p<0.05$) in the T_1 group, followed by the T_3, $T_{4,\ T2,}$ and T_5 groups, who had the lowest weight gain values. However, there was no significant difference between the T_4 and T_5 groups. The results were in close

agreement with the findings of Ndelekwute et al. (2015), Sindhu et al. (2018), and Dozo et al. (2023), who had also reported a non-significant effect of black pepper on body weight gain. On the other hand, the findings of the present study were contradictory to the observations of Abou-Elkhair et al. (2014), Tazi et al. (2014), and Aikpitanyi et al. (2019), who observed increased weight gain when supplemented with black pepper.

3.3 Feed Intake

From the data given in Table 2, it was perused that the total feed intake during the experiment was 4075.40, 4192.93, 4125.21, 4132.00, and 4139.80 g/bird for T_1, T_2, T_3, T_4, and T_5 groups, respectively. The corresponding mean feed intake was recorded as 452.82, 465.88, 458.36, 459.11, and 459.98 g/bird/week, respectively. From the perusal of data, it was observed that the average value of feed intake was significantly ($P<0.05$) highest in T_2, followed by T_5, T_4, and T_3, and lowest in the T_1 group. However, the difference amongst T_1, T_3, and T_4 was found to be non-significant. The present findings were well corroborated with the reports of Al-Kassie et al. (2011) and Tazi et al. (2014), who had observed increased feed intake as a result of black pepper supplementation. Contrary to the present findings, Ndelekwute et al. (2015) and Dozo et al. (2023) had reported that supplementation of black pepper did not show any significant effect on feed intake. It may be due to increased regulation of various metabolic functions, which might have increased intake and productivity of the animal, Toghyani et al. (2010).

3.4 Feed Conversion Efficiency

From the Table 2, it was observed that the average value of feed conversion efficiency of vanaraja birds during first week was 0.80, 0.77, 0.88, 0.88 and 0.83. At the end of ninth week, the values were recorded as 0.33, 0.31, 0.32, 0.31 and 0.30 for T_1, T_2, T_3, T_4 and T_5 groups, respectively. The overall mean feed conversion efficiency of vanaraja birds was 0.48, 0.48, 0.48, 0.49 and 0.49 for T_1, T_2, T_3, T_4 and T_5 groups, respectively. From the perusal of data, it was observed that there was no significant difference amongst T_2, T_3, T_4 and T_5 groups. The present findings were well corroborated with the reports of Ndelekwute et al. (2015) who also observed that inclusion of black pepper did not show any significant effect on feed conversion efficiency. Contrary to the present findings, Al-Kassie et al. (2011) and Shahverdi et al. (2013) observed that feed conversion efficiency was better in group fed with black pepper as compared to control group.

3.5 Mortality and Morbidity

The mortality, liveability percentage, and performance index (PI) from day old to nine weeks old for the different treatment groups are shown in Table 2. The mortality percentages at 9th week for T_1, T_2, T_3, T_4, and T_5 are 6.66, 6.66, 3.33, 0.00, and 3.33 percent, respectively. The values of mortality were within the standard limit. However, the mortality was not due to black pepper feed supplementation but to external forces. And as a result, liveability percentages were recorded to be 93.34, 93.34, 96.67, 100.00, and 96.67, respectively. The highest performance of vanaraja birds was observed in T3, followed by T_4, T_1, T_5, and the lowest in the T_2 group. Rahimian et al. (2016) had reported similar findings that the supplementation of black pepper powder had good effects on the performance of chickens compared to the control group. However, variation in the observation might be due to differences in species of birds, level of black pepper powder, inclusion, and agro-climatic condition.

3.6 Carcass Yield, Dressing Percentage and Organ weight

The mean carcass weight of vanaraja birds in different experimental groups was 1057.80, 1125.00, 1073.00, 1135.40, and 1142.60 g/bird for T_1, T_2, T_3, T_4, and T_5, respectively. The highest carcass weight was in T_5, followed by T_4, T_2, T_3, and T_1 groups. However, from the statistical analysis, the carcass weight was significantly ($P<0.05$) higher in T_5 and lowest in T_1. The average dressing percentage at the end of the 9th week of different treatment groups T_1, T_2, T_3, T_4, and T_5 were recorded as 67.51, 72.17, 71.11, 66.41, and 69.30 percent, respectively. The dressing percentage was found to be higher in T_2, followed by T_3, T_5, T_1, and T_4 groups. From the statistical analysis, the dressing percentage was significantly ($P<0.05$) higher in T_2 (72.17%), but there was no significant difference between T_4 and T_5. The average liver weight was 37.60, 43.40, 43.40, 41.20, and 40.80 for T_1, T_2, T_3, T_4, and T_5 groups, respectively. The highest liver weight was recorded in T_2, followed by T_3, T_4, and T_5, and the lowest in the T_1 group. The average weight of spleen for T_1, T_2, T_3, T_4, and T_5 groups was 2.08, 2.14, 2.16, 3.00, and 2.78

gram, respectively. The spleen weight was higher in T_4, T_5, T_3, T_2, and T_1, respectively. Statistical analysis revealed that T_4 was significantly ($P<0.05$) higher than T_1. In T_1, T_2, T_3, T_4, and T_5 groups, respectively, the average gizzard weight was 26.00, 30.60, 31.00, 30.80, and 27.80 gram. A higher gizzard weight was observed in the T_3 group, followed by T_4, T_2, T_5, and T_1, respectively. Statistical analysis revealed that the gizzard weight was significantly ($P<0.05$) higher in T_3 and lowest in T_1, but there was no significant difference between T_2, T_3, and T_4. The average heart weight for the T_1, T_2, T_3, T_4, and T_5 groups was 8.40, 8.60, 9.60, 10.60, and 9.80 g. The highest heart weight was found in T_4 and subsequently T_5, T_3, T_2, and least in T_1 group. Statistical analysis revealed that the heart weight was significantly ($p<0.05$) higher in T_4, but there was no significant difference between T_1, T_2, T_3, and T_4. The present findings were well collaborated with the reports of Mansoub (2011), Tazi et al. (2014), Singh (2014), Rahimian et al. (2016), and Puvaca et al. (2019), where observations of carcass yield, dressing percentage, and organ weights increased after black pepper was supplemented into the feed.

3.7 Haematological and Biological Parameter

i. Total leucocytes count: From the Table 3, it was revealed that the values of the average TLC concentration of Vanaraja birds at 9th week in T_1, T_2, T_3, T_4 and T_5 groups were 222.51, 225.90, 233.30, 231.05 and 225.62 cumm, respectively. The values of TLC was significantly ($P<0.05$) higher in T_3 and the least in control group.

ii. Haemoglobin: The average values of haemoglobin (Hb) on the 9th week of age were 14.40, 15.05, 15.85, 15.30, and 13.85 g/dl for T_1, T_2, T_3, T_4, and T_5 groups, respectively. The value of haemoglobin in the T3 group was significantly ($p<0.05$) higher than the other groups. However, the haemoglobin levels did not show significant differences among the treated groups and control group. This finding was similar to Al-Kassie et al. (2011), who also observed no significant increase in Hb level in the treated group as compared to the control group. On the contrary, Ndelekwute et al. (2017) found significant increases in haemoglobin concentration when supplemented with black pepper powder.

iii. Red blood cell: The average values for red blood cells (RBC) obtained were 2.64, 2.53, 2.63, 2.35, and 2.29 106/ul for T_1, T_2, T_3, T_4, and T_5, respectively. The value of RBC was numerically higher in the T_1 group, followed by T_3, T_2, T_4, and the lowest in the T_5 group. However, the values obtained showed that there was no significant difference amongst the groups. The findings were similar to Al-Kassie et al. (2011), who also observed no significant increase in RBC level in the treated group as compared to the control group. The results of the present study were contrary to the findings of Ndelekwute et al. (2017), who reported increased RBC count on diet supplemented with black pepper powder.

iv. Packed cell volume: The values of the average HCT (PCV) values of Vanaraja birds were 30.45, 29.40, 31.22, 29.15, and 29.65 for T_1, T_2, T_3, T_4, and T_5, respectively. The value of HCT was numerically higher in T_3 PVC level in the treated group as compared to the control group. In contrast, the findings observe, followed by T_1, T_5, T_2, and the lowest in T_4. However, the values obtained showed no significant difference amongst the group. Al-Kassie et al. (2011) also observed no significant increase in ed in the present study by Ndelekwute et al. (2017) reported that there was an increase in the PCV value of the treated group.

v. Total cholesterol: The average values of total cholesterol in the T_1, T_2, T_3, T_4, and T_5 groups were 183.30, 163.46, 173.49, 172.79, and 181.03 mg/dl, respectively. The value of total cholesterol was significantly ($P<0.05$) higher in T_1, followed by T_5, T_3, T_4, and the least in T_2 groups. A similar finding was also observed by Al-Kassie et al. (2011), Rahimian et al. (2016), and Mansoub (2011), who reported that supplementation of black pepper decreased cholesterol levels compared to the control group.

vi. High-density lipoprotein (HDL): The average values of HDL cholesterol of vanaraja birds in different treatment groups were 38.64, 32.88, 33.29, 33.99, and 36.94 mg/dl for T_1, T_2, T_3, T_4, and T_5 groups, respectively. The value of HDL was significantly ($P<0.05$) highest in T_1, followed by T_5, T_4, T_3, and the lowest in the T_2 group. However, the values obtained showed no significant distinction between the T_2, T_3, T_4, and T_5 groups. The present study's conclusion was strongly supported by the observations of Al-Kassie et al. (2011), who also reported a decreased level of HDL than the control group with a diet supplemented with black pepper.

Table 2. Production performance of broiler chicken with the supplemented black pepper on the different treatments groups of Vanaraja Birds

Parameter	Treatments					
	Week	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**
Body weight (gram/bird/week)	Onset	31.66	31.40	30.40	32.20	32.20
	9th	1695.2[a]	1738.2[c]	1719.6[b]	1717.6[b]	1714.2[b]
	Total	7204.88	7473.9	7349.7	7405.2	7402.89
	Overall mean	800.54	830.43	816.63	822.80	822.54
Body Weight Gain (gram/bird/week)	Onset	49.97	48.95	53.88	53.97	48.10
	9th	255.8[b]	247.2[ab]	253.2[b]	251.2[a]	243.8[a]
	Total	1649.92	1704.79	1630.86	1685.2	1673.56
	Overall mean	183.32	189.42	181.20	187.25	185.95
Feed Intake (gram/bird/week)	Onset	62.20	63.40	60.60	61.20	58.13
	9th	785.2[a]	815.2[b]	798.2[a]	801.2[a]	807.6[ab]
	Total	4075.40	4192.93	4125.21	4132.0	4139.8
	Overall mean	452.82	465.88	458.36	459.11	459.98
Feed Conversion Efficiency	Onset	0.80	0.77	0.88	0.88	0.83
	9th	0.33[b]	0.31[a]	0.32[a]	0.31[a]	0.3[a]
	Total	4.38	4.40	4.33	4.42	4.42
	Overall mean	0.48	0.48	0.48	0.49	0.49
Mortality	1st -9th	6.66	6.66	3.33	0.00	3.33
Liveability (%)	9th	93.34	93.34	96.67	100.00	96.67
Performance index	9th	471.7	451.94	479.76	472.02	465.36
Dressing (%)	9th	67.5[ab]	72.17[b]	71.11[b]	66.41[a]	69.30[a]
Carcass weight (gram)	9th	1057.8[a]	1125.0[ab]	1073.0[ab]	1135.4[b]	1142.6[c]
Heart (gram)	9th	8.4[a]	8.6[a]	9.60[a]	10.6[b]	9.8[a]
Liver (gram)	9th	37.6[a]	43.4b	43.4b	41.2[ab]	40.8[ab]
Gizzard (gram)	9th	26.0[a]	30.6[b]	31.0[b]	30.8[b]	27.8[ab]
Spleen (gram)	9th	2.08[a]	2.14[ab]	2.16[ab]	3.00[c]	2.78[b]

a, b and c mean bearing different superscripts in a column differ significant (P<0.05)

Table 3. Average blood biochemical constituents of Vanaraja birds in different treatment groups

Treatments	Biochemical Characteristics			
	Total Cholesterol (mg/dl)	HDL Cholesterol (mg/dl)	LDL Cholesterol (mg/dl)	Triglycerides (mg/dl)
(T_1)	183.30^{b}	38.64^{b}	125.56^{c}	124.81^{b}
(T_2)	163.46^{a}	32.88^{a}	110.15^{ab}	118.79^{a}
(T_3)	173.49^{ab}	33.29^{a}	105.29^{a}	121.88^{ab}
(T_4)	172.79^{b}	33.99^{a}	114.72^{ab}	122.41^{ab}
(T_5)	181.03^{b}	36.94^{a}	120.36^{b}	123.22^{b}
***SEm*±**	**3.53**	**1.41**	**2.65**	**0.97**
CD (p=0.05)	**13.88**	**5.55**	**10.41**	**3.82**

a,b,c means bearing different superscript in the column differ significantly (P<0.05)

Table 4. Average haematological characteristics of Vanaraja birds in different treatment groups

Treatments	Haematological Characteristics			
	Total Leucocytes Count (TLC) (Cumm)	Haemoglobin (gm/dl)	Red Blood Cells (RBC)(10^6/ul)	HCT (PVC) (%)
(T_1)	222.51^{a}	14.40^{a}	2.64^{a}	30.45^{a}
(T_2)	225.90^{ab}	15.05^{a}	2.53^{a}	29.40^{a}
(T_3)	233.30^{c}	15.85^{a}	2.63^{a}	31.22^{a}
(T_4)	231.05^{b}	15.30^{a}	2.35^{a}	29.15^{a}
(T_5)	225.62^{a}	13.85^{a}	2.29^{a}	29.65^{a}
***SEm*±**	1.32	0.73	0.16	0.86
CD (p=0.05)	5.19	NS	NS	NS

a,b,c means bearing different superscript in the column differ significantly (P<0.05)

vii. Low density lipoprotein (LDL): The average values of LDL cholesterol were 125.56, 110.15, 105.29, 114.72, and 120.36 mg/dl for the T_1, T_2, T_3, T_4, and T_5 groups, respectively. The value of LDL was significantly (P<0.05) higher in T1, followed by T_5, T_4, T_2, and the lowest in T_3 groups. The findings of the present study were strongly supported by the observations of Rahimian et al. (2016), who also reported a decreased level of LDL than the control group with a diet supplemented with black pepper.

viii. Triglyceride: It was observed that the average values of triglycerides in the T_1, T_2, T_3, and T_4 groups were 124.81, 118.79, 121.88, 122.41, and 123.22 mg/dl, respectively. The value of triglyceride was significantly (P<0.05) higher in T_1, followed by T_5, T_4, T_3, and the lowest in the T_2 group. The finding of the present study was well corroborated with the observations of Rahimian et al. (2016), who also reported that the triglyceride value decreased with feed containing a supplement with black pepper.

3.8 Cost of Production

The average production cost of vanaraja birds in different treatment groups. The average cost of production per bird was 280.82, 301.82, 313.68, 328.78, and 344.15 rupees per bird for groups of T_1, T_2, T_3, T_4, and T_5, respectively. The comparable figures for the average production cost per kg of live bird were 166.16, 174.46, 183.43, 183.67, and 201.25 rupees. The net profit per bird was 145.01, 134.76, 116.15, 118.15, and 86.43 rupees for groups of T_1, T_2, T_3, T_4, and T_5, respectively, and the corresponding values for net profit per kg of live weight were 101.40, 90.44, 80.10, 80.92, and 58.79 rupees. The benefit cost ratio was calculated as 1.51, 1.44, 1.37, 1.31, and 1.25 for T_1, T_2, T_3, T_4, and T_5, respectively. The cost of production was maximum in T5 (Rs. 344.15) and the least in T_1 (Rs. 280.82). The total cost of production per kg of live weight of bird was recorded to be highest in T_4 (Rs. 201.25) and lowest in T_1 (Rs. 166.16). The net profit per bird and net profit per live kg were observed to be higher in T_1 (Rs. 145.01 and Rs. 101.40, respectively) and lower in T_5 (Rs. 86.43 and Rs. 58.79, respectively). The benefit-cost ratio was highest in T_1, followed by T_2, T_3, T_4, and the lowest in the T_5 group. From the results obtained in the present study, it may be concluded that the birds in the control group had a better economical return as compared to the birds supplemented with black pepper. Contrary to

present findings, Tazi et al. (2014) and Dozo et al. (2023) found that the birds supplemented with black pepper powder were found to be economical. The variation in the results might be due to differences in the species/strains and agro-climatic conditions.

4. CONCLUSION

The treatment group T_2 had significantly ($P<0.05$) higher body weight, followed by T_3, T4, and T_5 the least in the control group, and body weight gain in the T_1 group. It was observed that the average value of feed intake was significantly ($P<0.05$) highest in T_2, followed by T_5, T_4, and T_3, and lowest in the T_1 group. However, the feed conversion was comparable irrespective of treatments. The performance index was better in the T_3 group. The carcass weight was comparable by supplementation of black pepper, while the higher dressing percentage and liver weight were found in the T_2 group. The values of hematological blood parameters were highest in T_3 for TLC, hemoglobin, and HCT (PVC). However, the values for RBC were highest in T_1. The values of blood constituents were highest in T_1 for cholesterol, HDL, and triglycerides. However. These values were lowest in the T_2 group. As for LDL, it was found higher in T_3 and lowest in T_2. From the present experiment on the basis of the above observations, it may be concluded that the performance of vanaraja birds in terms of body weight, feed intake, dressing percentage, liver weight, and biochemical constituents of blood were better in T_2 groups as compared to other treatments. Hence, on the basis of the above findings, dietary supplementation of black pepper (*Piper nigrum*) powder at the rate of 0.25 g/kg of basal can be advocated for better performance of vanaraja birds.

4.1 Future Plans

1. Similar studies under different agro - climatic conditions and altitudes need to be carried out.
2. Additional research should be conducted on the inclusion of Paper Mulberry leaf meal in the diets of various pig breeds and age groups.
3. Further studies need to be carried out to evaluate the effect of Paper Mulberry leaves as feed supplementation at higher levels.
4. Further studies need to be carried out for a longer period of time to see results.
5. Additional studies are necessary to assess the impact of Paper Mulberry leaves on various other parameters, such as milk secretion and diarrhea, among others.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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