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Effect of dietary linseed supplementation on hematological and serum biochemical parameters and meat quality in broiler chickens

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Abstract

The present study assessed the effects of dietary supplementation with linseed on the hematological and serum biochemical profile, physicochemical properties, texture profile, and sensory quality of broiler chicken meat. Two hundred one-day-old Cobb-400 broiler chicks were randomly distributed among five dietary treatments groups of 0, 2.5, 5.0, 7.5, and 10.0% linseed. Each treatment was replicated five times, with eight chicks in each replicate. The birds were reared in deep litter system for 42 days under normal management conditions. The experimental diets were designed for two phases: starter (7–21 days) and finisher (22–42 days). There were significant ($P<0.01$) increases in red blood cell count, hemoglobin concentration, packed cell volume, white blood cell count, lymphocyte percentage, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, and platelet count in dietary linseed supplemented birds, whereas no significant changes were observed remaining hematological parameters. Increasing inclusion levels of linseed significantly increased serum total protein levels and decreased serum creatinine levels and activity of aspartate aminotransferase, suggesting enhanced metabolic status and normal hepatic and renal function. Serum albumin concentrations and albumin/globulin ratio decreased significantly but remained within the normal range, while the concentrations of globulin and uric acid, and Alanine Aminotransferase activity remained unchanged. The supplementation of linseed did not significantly affect the meat physicochemical characteristics, except that it increased the crude fat content of both breast and thigh muscles. Texture profile analysis revealed that the cohesiveness, springiness, and shear force values of thigh meat improved while tenderness was not affected, whereas gumminess and chewiness of breast meat improved without affecting tenderness. Sensory evaluation indicated that the 5% linseed treatment resulted in numerically higher overall acceptability of chicken meat, although no statistical differences were observed between the treatment groups. It was concluded that dietary linseed supplementation in broiler chicken diets cab be done up to 10% without any adverse effects on the hematological and serum biochemical profile, meat quality, and sensory acceptability of meat in broiler chicken.

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1. Introduction

Meat is a vital source of protein, lipids, iron, zinc, and Vitamin B complex. Over the past few decades, worldwide production and consumption of broiler meat have increased (Smith et al. 2022). Increasing awareness among consumers that their diet has a direct impact on their health has led to growing interest in fortification of animal-origin foods with biologically active substances. Feeding low quality feeds to poultry negatively affects meat quality, including nutritional value, flavor, tenderness, and food safety (Choi et al. 2023). Low-quality or contaminated poultry feed can negatively affect the bird health, alter blood parameters, induce oxidative stress, reduce nutrient assimilation, and compromise the quality of meat and public safety. There may be higher chances of bacterial contamination (e.g., Salmonella), fat to protein ratio imbalance (particularly due to mycotoxins), and muscles abnormalities that reduces meat quality and makes it a potential source of foodborne illness (Salahi et al. 2025). Significant improvements have been reported in the serum biochemical parameters of broiler chicken fed flaxseed meal for different duration (Kumar et al. 2021). Moreover, the dietary supplementation of flaxseed meal in broiler chicken did not show any negative effect on sensory parameters of broiler chicken meat (Mir et al. 2018; Mridula et al. 2011). Mir et al. (2021) also reported improved serum biochemical profiles of broiler chicken fed flaxseed meal and chromium. In broiler chickens, omega-3 fatty acid supplementation significantly improved meat quality parameters, including water holding capacity and softness, while also positively regulating blood parameters, such as cholesterol levels, and desirable high-density lipoprotein (HDL) levels (Idowu et al. 2026).

Linseed (*Linum usitatissimum*) is rich in polyunsaturated and monounsaturated fatty acids (PUFAs/MUFAs) and can serve as a major source of fat and oil for inclusion in chicken diets. Linseed contains about 40% oil and has a high proportion of α-linolenic acid (ALA: 50-60% of the total fatty acids). Moreover, it has a lower proportions of linoleic acid and saturated fatty acids (SFAs) compared to soybean, cottonseed, and sunflower seeds (Neetika et al. 2019). Linseed possesses significant levels of omega-3 PUFAs, which potentially decrease the susceptibility to coronary artery diseases, hypertension, and diabetes. However, linseed possesses several antinutritional factors that could restrict its use in broiler chicken diets, such as mucilages from the hulls, antithiamine dipeptides (linatin), cyanogenic glycosides, and trypsin inhibitors (Tamasgen 2022).

Although dietary supplementation of linseed has been studied in broiler chicken diets, very few studies are available on the combined effects of graded level of its supplementation (0–10%) on hematological parameters, meat physicochemical properties, and texture and sensory characteristics. Thus, it was hypothesized that dietary supplementation of broiler chicken diets with different levels of linseed would influence blood profile and meat quality parameters of broiler chicken. Therefore,

this study was undertaken to assess the impact of different levels of dietary linseed on the hematological parameters, physicochemical characteristics, and texture and sensory qualities of broiler chicken meat.

2. Materials and Methods

2.1 Experimental design, animals and diet management

The study was undertaken at the chicken farm of the Department of Dairy Science and Food Technology, Banaras Hindu University, India. A total of 200 one-day-old male broiler chicks (Cobb-400) were procured from Pratap Hatchery, Varanasi. The chicks were raised for one week on a pre-starter diet under a deep litter system prior to the experimental trial. The chicks were weighed after one week and randomly divided into five experimental groups according to their weights. Four experimental diets containing linseed at the levels of 2.5%, 5%, 7.5%, and 10% were formulated, along with a control diet without linseed. Each experimental group contained five replicates, having eight birds in each replicate, making 40 birds per treatment group. Ad libitum feed and drinking water was provided to the birds throughout the experimental period. All birds were vaccinated as per the standardized schedule. Ambient temperature was gradually decreased from 33 °C on day 1 to ~24 °C at the end of the experiment as per the requirement of the birds. Five iso-caloric and iso-nitrogenous diets were formulated and the composition of each is presented in Table 1 (Rathaur et al. 2022). The samples of linseed fed to the broiler chickens were evaluated for proximate principles according to AOAC (2005).

2.2 Hematological and blood biochemical profile

After 42 days of the study, two birds were randomly selected from each

Table 1. Ingredient and nutrient composition of broilers starter and finisher ration

Ingredients (%)	Starter phase (7 - 21 days)					Finisher phase (22 - 42 days)				
	0%	2.5%	5.0%	7.5%	10.0%	0%	2.5%	5.0%	7.5%	10.0%
Maize	51.05	49.15	47.06	45.63	44.1	59.23	57.91	56.65	54.43	53.12
Soybean meal	38.4	37.55	37.14	36.57	35.6	25.56	24.33	23.14	22.87	21.68
Wheat bran	5	5	5	5	5	5	5	5	5	5
Vegetable oil	2	2	2	2	2	7	7	7	7	7
Dicalcium phosphate	1.1	1.25	1.25	1.25	1.25	1	1	1	1	1
Shell grit	1	1	1	0.5	0.5	1	1	1	1	1
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Minerals premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamins premix*	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.1	0.1	0.1	0.1	0.1	0.01	0.01	0.01	0	0
DL-Methionine	0.15	0.25	0.25	0.25	0.25	0.1	0.15	0.1	0.1	0.1
Vitamin E	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Linseeds	0	2.5	5	7.5	10	0	2.5	5	7.5	10
Calculated composition										
Dry matter	88.92	89.38	89.67	89.89	90.04	89.84	90.05	90.12	90.1	90.22
Crude protein	22.2	22.21	22.24	22.25	22.27	19.18	19.28	19.88	19.36	19.32
Crude fibre	4.56	4.89	5.23	5.78	5.94	4.84	5.1	5.32	5.89	5.92
Lysine	1.27	1.3	1.38	1.35	1.34	1.08	1.1	1.08	1.12	1.15
Methionine	0.48	0.5	0.53	0.54	0.62	0.38	0.42	0.44	0.45	0.39
Calcium	1.1	1.12	1.15	1.17	1.19	1.08	1.12	1.31	1.3	1.07
Phosphorus	0.58	0.62	0.65	0.67	0.71	0.59	0.65	0.69	0.57	0.55
ME kcal/kg diet	2962.34	2983.54	2958.51	2970.74	2992.84	3185.65	3195.68	3210.04	3225.25	3227.85

[1] Supplied per kg: Vitamin A 8000 U; Vitamin D3 8560 U; Vitamin E 95 U; Vitamin B12 4.5 mg; Niacin 45 mg; Pyrodoxin 4 mg; Thiamin 5 m; Biotin 0.2 mg; Panthotenic acid 20 mg; Riboflavin 08 mg. [2] Supplied per kg: Iodine (Calcium iodate) 2 mg; Copper (Cupric sulfate pentahy-drate) 8 mg; Manganese (Manganese sulfate monohy-drate) 100 mg; Iron (Ferrous sulfate monohydrate) 55 mg; Zinc (Zinc sulfate monohydrate) 70 mg; Selenium (Sodium selenite) 0.15 mg

replicate (10 birds per treatment group) and 5 mL of blood sample was collected from the wing vein of each bird into heparinized tubes. Samples in glass tube were placed in an icebox. Hematological analysis was carried out within 2 h of blood collection. Using a Hematological Analyser Sysmex XP- 100 according to the manufacturer's instructions, the parameters measured were red blood cell count (RBC), hemoglobin (Hb), packed cell volume (PCV), white blood cells (WBC), lymphocytes, monocytes, eosinophils, basophils, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and Platelets.

At the end of the experiment, again two birds were selected at random from each replicate, and 5 mL blood was drawn out from the wing vein into non-heparinized tubes without anticoagulants. Serum was separated from the blood samples by centrifugation at 2000 rpm for 10 min. Serum total protein, albumin, globulin, uric acid, creatinine, aspartate amino transferase (AST), alanine amino transferase (ALT) were measured using EM200 fully automatic biochemical analyzer.

2.3 Texture profile

At the end of the 42 days, textural measurements of the raw chicken meat from the left part of the thigh and breast samples were performed according to Ciurescu et al. (2023), with slight modifications. The samples were analyzed with computer assisted Text-plus Textural Analyser under the following conditions: trigger load 5 g, test speed 5 mm/s, return speed 5 mm/s, pretest speed 2 mm/s, and load cell 50,000 g. Hardness, cohesiveness, springiness, gumminess, chewiness, and shear force were measured for each meat sample placed on fixture base table. The raw meat samples from each chicken were placed centrally under the TA 44 probe and shot perpendicular to the sample surface.

2.4 Physicochemical attributes

The moisture (Method 930.15), crude protein (Method 988.05), fat (Method 2003.06), and ash content (Method 942.05) of the raw breast and thigh meat samples were analyzed according to AOAC (2005). All results were expressed on a wet-weight basis.

2.5 Sensory evaluation

Sensory evaluation was carried out according to Adegbeye et al. (2020), with slight modifications. Fifteen trained panelists were selected from International Hostel of Banaras Hindu University, Varanasi. After slaughter, chicken meat samples from breast and left thigh were collected. The samples were wrapped in aluminum foil and cooked for 40 min at 200 °C in an oven prior to sensory evaluation. After cooking, the meat was cut into 1 cm cubes. Score cards were provided to 15 panel judges to record their sensory evaluation scores for each tested sample. The penal judges were instructed to rinse their mouths with lukewarm water between successive evaluations. The cooked meat samples of chicken breast and thigh were scored by each panelist on a 9-point Hedonic Scale ranging from 1 (dislike extremely) to 9 (like extremely) for various parameters, including acceptability, desirability, flavour, juiciness, tenderness, and colour.

2.6 Statistical analysis

The experiment was conducted using a completely randomized design and each treatment was replicated five times. One-way ANOVA was used for data analysis and Duncan's multiple test for post hoc mean comparisons. The IBM SPSS Statistics (version 25.0) was used for all the statistical analysis.

3. Results

3.1 Hematological and blood biochemical profile

The hematological parameters of broiler chickens are shown in Table 2. The present study revealed significant increase in RBC ($P < 0.01$), Hb (P

Table 2. Effect of feeding linseed supplemented diets on hematological profile of broiler birds

Attributes	Level of linseed (%)					SEM	P-value
	0%	2.5%	5.0%	7.5%	10.0%		
RBC (10^6/mm^3)	2.27^c	2.32^b	2.40^a	2.41^a	2.42^a	0.01	<0.01
Hb (g/dl)	4.28^d	9.96^c	10.08^b	10.21^{ab}	10.26^a	0.06	<0.01
PCV (%)	29.48^d	29.46^c	30.42^{bc}	31.35^b	32.31^a	0.10	<0.01
WBC ($10^3/\mu$l)	4.78^e	4.90^d	5.27^c	5.78^b	5.91^a	0.01	<0.01
Lymphocytes (%)	61.40^d	61.51^c	61.91^b	62.63^{ab}	62.72^a	0.25	<0.01
Monocytes (%)	5.73	5.70	5.68	5.65	5.62	1.02	0.850
Eosinophils (%)	4.73	4.72	4.71	4.70	4.69	1.39	0.133
Basophils (%)	1.31	1.32	1.34	1.36	1.38	1.27	0.180
MCV(fl)	129.28^d	129.50^c	129.73^b	129.89^{ab}	129.92^a	0.18	<0.01
MCH (pg)	43.20^d	43.72^c	43.85^b	44.12^{ab}	44.25^a	0.14	<0.01
MCHC (g/dl)	33.48^c	33.50^{bc}	34.12^b	34.22^{ab}	34.32^a	0.01	<0.01
Platelets ($10^3/\mu$l)	5.00^e	6.10^d	6.90^c	7.20^b	7.35^a	0.02	<0.01

Different superscripts in each row indicate significant differences ($P < 0.05$); RBC: red blood cell count, Hb: hemoglobin, PCV: packed cell volume, WBC: white blood cell count, MCV: mean corpuscular volume, MCH: mean corpuscular hemoglobin, MCHC: mean corpuscular hemoglobin concentration, mm^3: cubic millimeter, fl: femtoliter, pg: pictogram, g: gram, dl: deciliter, μl: microliter

Table 3. Effect of feeding linseed supplemented diets on blood biochemical profile of broiler birds

Attributes	Level of linseed (%)					SEM	P-value
	0%	2.5%	5.0%	7.5%	10.0%		
Total protein (mg/dl)	7.47^{d}	7.48^{d}	7.52^{c}	7.55^{b}	7.58^{a}	0.01	<0.01
Albumin (mg/dl)	4.28^{a}	4.04^{b}	3.95^{c}	3.86^{d}	3.80^{d}	0.05	<0.01
Globulin (mg/dl)	3.18	3.19	3.20	3.21	3.22	1.24	0.842
A:G ratio	1.35^{a}	1.27^{b}	1.23^{c}	1.20^{c}	1.18^{d}	0.02	<0.01
Creatinine (mg/dl)	0.78^{a}	0.76^{ab}	0.75^{bc}	0.74^{c}	0.73^{c}	0.01	<0.01
Uric acid (mg/dl)	5.48	5.42	5.40	5.39	5.37	1.01	0.124
ALT (U/L)	12.80	12.83	12.85	12.87	12.89	1.12	0.210
AST (U/L)	180.60^{a}	178.56^{b}	177.33^{bc}	175.47^{c}	174.37^{d}	0.57	<0.01

Mean bearing different superscript in a row differ significantly ($P < 0.05$); SEM: Total standard error of the mean; AST: Aspartate aminotranferase; ALT: Alanine aminotransferase; dl: deciliter; U/L: units/liter; mg: milligram

< 0.01), PCV ($P < 0.01$), WBC ($P < 0.01$), lymphocytes ($P < 0.01$), MCV ($P < 0.01$), MCH ($P < 0.01$), MCHC ($P < 0.01$) and platelets ($P < 0.01$) in birds supplemented with linseed from 7 to 42 days. However, monocyte, eosinophil, and basophil percentages were not affected ($P > 0.05$) by the inclusion of linseed in the broiler chicken diet.

Table 3 shows the effect of dietary supplementation of linseed on serum biochemical parameters of broiler chickens. Increasing levels of linseed supplementation in the diet significantly ($P < 0.05$) altered serum biochemical profile except for globulin, uric acid, and ALT. Serum concentration of total protein increased significantly ($P < 0.05$) in birds fed increasing levels of linseed, whereas serum concentration of albumin and creatinine decreased significantly along with decline in activity of aspartate aminotransferase. Also serum albumin/globulin ratio decreased significantly but remained within the normal range.

3.2 Texture profile

The texture profile parameters of the broiler chickens (breast and thigh meat) are shown in Table 4. There were no significant differences in hardness, cohesiveness, springiness, and shear force of breast meat. However, significant ($P < 0.05$) increase in gumminess and chewiness as the percentage of linseed in the diet increased. Thigh meat sample did not show significant differences for attributes of hardness, gumminess, and chewiness. The cohesiveness was found to be significantly different with increasing levels of linseed in the diet. The degree of springiness and shear force of the diet was significantly ($P < 0.05$) affected by the amount of linseed fed.

Table 4. Effect of feeding linseed supplemented diets on textural properties breast and thigh meat of broiler chickens

Attributes	Level of linseed (%)					SEM	P-value
	0%	2.5%	5.0%	7.5%	10.0%		
Breast meat							
Hardness (mJ)	52.02	52.11	52.19	52.25	52.32	1.05	0.140
Cohesiveness	0.27	0.28	0.28	0.30	0.31	0.21	0.073
Springiness (mm)	10.60	10.63	10.65	10.67	10.69	0.47	0.120
Gumminess (g)	266^{a}	269^{b}	271^{b}	273^{c}	275^{c}	0.01	<0.01
Chewiness (mJ)	54.32^{c}	54.35^{c}	54.40^{b}	54.46^{a}	54.52^{a}	0.01	<0.01
Shear force cm^2/kg	1.04	1.06	1.07	1.07	1.08	0.01	0.143
Thigh meat							
Hardness (mJ)	17.30	17.31	17.34	17.38	17.42	0.64	0.150
Cohesiveness	0.64^{c}	0.66^{b}	0.66^{b}	0.68^{a}	0.68^{a}	0.02	0.003
Springiness (mm)	10.88^{d}	10.90^{d}	10.91^{c}	10.93^{a}	10.95^{a}	0.01	<0.01
Gumminess (g)	275	274	273	272	270	0.70	0.102
Chewiness (mJ)	28.38	28.40	28.42	28.44	28.45	0.674	0.074
Shear force cm^2/kg	1.44^{d}	1.47^{c}	1.48^{b}	1.48^{b}	1.50^{a}	0.10	<0.01

Mean bearing different superscript in a row differ significantly ($P < 0.05$); SEM, total standard error of the mean

Table 5. Effect of feeding linseed supplemented diets on physico-chemical properties and nutritional composition of meat of broiler chickens

Attributes	Level of linseed (%)					SEM	P-value
	0%	2.5%	5.0%	7.5%	10.0%		
Breast meat							
Moisture (%)	71.40	71.38	71.37	71.36	71.36	0.017	0.140
Crude protein (%)	21.76	21.79	21.83	21.85	21.87	0.033	0.055
Fat (%)	0.63^{d}	0.80^{c}	1.20^{b}	1.38^{ab}	1.42^{a}	0.105	<0.01
Ash (%)	0.74	0.73	0.72	0.71	0.70	0.146	0.231
Thigh meat							
Moisture (%)	73.23	73.22	73.21	73.20	73.18	0.014	0.088
Crude protein (%)	19.02	19.06	19.11	19.13	19.15	0.036	0.897
Fat (%)	2.02^{d}	2.25^{c}	2.43^{bc}	2.52^{b}	2.56^{a}	0.015	<0.01
Ash (%)	0.63	0.62	0.61	0.61	0.59	0.016	0.100

Mean bearing different superscript in a row differ significantly (P < 0.05); SEM, total standard error of the mean

3.3 Physicochemical attributes

The physicochemical attributes of broiler chicken meat (breast and thigh) are shown in Table 5. There were no notable differences found among the physicochemical attributes of breast and thigh meat except for crude fat. The crude fat content of the breast and thigh meat was significantly (P < 0.05) higher as linseed content in the ration was increased. The 10% linseed treatment showed the highest crude fat content whereas 0% linseed showed the lowest in both breast and thigh meat.

3.4 Sensory analysis

Table 6 shows the sensory parameters of broiler chicken meat based on a 9-point hedonic scale readings. Diet supplementation with linseed did not negatively affect (P > 0.05) any of the sensory parameters of the breast and thigh meat samples. However, numerically the highest overall acceptance was for the 5% linseed level in both breast and thigh meat, followed by the 2.5%, 7.5%, and 10% linseed levels.

4. Discussion

The present study demonstrated that dietary linseed supplementation significantly improved the hematological profile of broiler chickens, which was demonstrated by increase in RBC, Hb, PCV, WBC, lymphocyte, MCV, MCH, MCHC, and platelet counts, while monocyte, eosinophil, and basophil percentages remained unaffected. These findings indicate enhanced hematopoietic activity, oxygen-carrying capacity, and immune competence without any adverse hematological effects. Such beneficial responses can be attributed to the high

Table 6. Effect of feeding linseed supplemented diets on sensory attributes of oven cooked breast and thigh meat of broiler chickens without salt

Attributes	Level of linseed (%)					SEM	P-value
	0%	2.5%	5.0%	7.5%	10.0%		
Breast meat							
Acceptability	8.40	8.20	8.60	8.20	7.80	0.16	0.482
Desirability	8.40	8.20	8.60	8.00	7.80	0.15	0.664
Flavour	9.00	8.60	9.00	8.80	8.60	0.09	0.611
Juiciness	8.60	8.21	8.60	8.40	8.00	0.12	0.511
Tenderness	8.60	8.40	8.40	8.20	8.20	0.11	0.896
Colour	8.60	8.40	8.60	8.40	8.20	0.13	0.894
Thigh meat							
Acceptability	8.70	8.70	8.80	8.60	8.60	0.09	0.941
Desirability	8.80	8.60	8.80	8.60	8.20	0.10	0.548
Flavour	9.00	8.80	9.00	8.80	8.60	0.09	0.671
Juiciness	8.80	8.40	8.80	8.40	8.20	0.11	0.477
Tenderness	8.80	8.60	8.60	8.60	8.40	0.10	0.693
Colour	8.80	8.80	8.80	8.60	8.60	0.11	0.980

concentration of α-linolenic acid (ALA), omega-3 polyunsaturated fatty acids, lignans, high-quality protein, and natural antioxidants present in linseed, which may improve erythrocyte membrane integrity, stimulate erythropoiesis, and reduce oxidative stress (Saastamoinen and Särkijärvi 2020; Patted et al. 2024; Mohammadkhani et al. 2025). The increase in MCV, MCH, and MCHC further reflects improved erythrocyte maturation and hemoglobin synthesis, whereas the higher WBC and lymphocyte counts suggest enhanced innate and adaptive immune responses through the immunomodulatory action of omega-3 fatty acids (Bodur et al. 2025). Similar improvements in hematological and immune parameters following flaxseed supplementation have also been reported earlier in broiler chickens (Ji et al. 2024). Furthermore, the increase in platelet count, while remaining within the normal physiological range, indicates improved hematopoietic function without any detrimental effect on blood coagulation (Hansen et al. 2002). The absence of significant changes in monocyte, eosinophil, and basophil percentages suggests that linseed supplementation did not markedly affect these parameters. Overall, the present findings suggest that dietary inclusion of linseed up to 10% may improve certain hematological parameters, supporting its use as a sustainable functional feed ingredient in broiler chicken ration (Weston et al. 2024).

The present study demonstrated that dietary supplementation of linseed up to the level of 10% significantly altered the serum biochemical profile of broiler chickens, indicating potentially enhanced metabolic efficiency and physiological health without any adverse effects on liver or kidney function. The progressive increase in serum total protein level reflects improved protein synthesis, nutrient utilization, and overall nutritional status, which may be attributed to the high-quality protein, α-linolenic acid (ALA), omega-3 fatty acids and antioxidant phytochemicals present in linseed (Szmek et al. 2025). Although serum albumin concentration and the albumin-to-globulin ratio decreased significantly, these values remained within the normal physiological range, while unchanged globulin levels suggest that humoral immunity was not adversely affected (Ramteke et al. 2025). The significant reduction in serum creatinine levels and AST activity indicates favourable changes in renal and hepatic function, whereas the absence of changes in uric acid levels and ALT activity suggests that linseed supplementation did not impair protein metabolism or liver integrity (Manterys et al. 2016). These beneficial effects are likely associated with the antioxidant and anti-inflammatory properties of omega-3 fatty acids, lignans, and phenolic compounds, which protect tissues against oxidative damage and improve metabolic function (Li et al. 2025). Similar findings have been reported in recent studies showing that flaxseed supplementation enhances protein metabolism, antioxidant status and organ health in poultry (Popescu et al. 2021; Embark et al. 2026). Overall, dietary inclusion of linseed up to 10% level can be considered a safe and effective nutritional strategy to improve serum biochemical health and enhance the production of functional omega-3-enriched broiler meat.

Dietary supplementation of linseed up to 10% had limited but beneficial effects on the texture profile of broiler chicken breast and thigh meat. In breast meat, hardness, cohesiveness, springiness, and shear force were not significantly affected ($P > 0.05$), indicating that linseed supplementation did not alter textural characteristics. However, gumminess and chewiness increased significantly ($P<0.01$), which may be attributed to changes in muscle protein interactions and the incorporation of omega-3 fatty acids into muscle cell membranes, resulting in improved muscle compactness without adversely affecting eating quality (Song et al. 2025). Similar findings have been reported by Cortinas et al. (2005), Betti et al. (2009), who observed that dietary flaxseed had minimal effects on breast meat texture while improving meat quality. In thigh meat, cohesiveness, springiness, and shear force increased significantly ($P < 0.01$), whereas hardness, gumminess, and chewiness remained unchanged ($P > 0.05$). The improvements in cohesiveness and springiness suggest enhanced muscle elasticity and structural stability, while the slight increase in shear force reflects a modest increase in firmness that remained within the acceptable range for broiler meat. These effects are likely due to the antioxidant activity of alpha-linolenic acid, lignans, and phenolic compounds present in linseed, which improve muscle integrity and oxidative stability (Gou et al. 2020). Overall, the results indicate that dietary linseed supplementation up to 10% level maintained desirable meat textural properties while producing slight improvements in selected textural attributes, supporting its use as a functional feed ingredient for producing nutritionally enriched broiler chicken meat (Rymer and Givens 2005; Kralik et al. 2018; El-Bahr et al. 2021).

Dietary supplementation of linseed up to 10% had minimal effects on the proximate composition of broiler chicken breast and thigh meat, with significant changes observed only in crude fat content. Moisture, crude protein, and ash contents of both breast and thigh meat were not significantly affected ($P > 0.05$), indicating that linseed inclusion did not alter the basic nutritional composition of the meat. These findings are in agreement with previous studies reporting that dietary flaxseed has little influence on moisture, protein, and mineral contents, while maintaining the overall nutritional quality of broiler meat (Cortinas et al. 2004; Rymer and Givens 2005; Kralik et al. 2018). In contrast, fat content increased significantly ($P < 0.01$) in both breast and thigh meat as the dietary level of linseed increased. This increase is attributed to the higher deposition of dietary lipids, particularly alpha-linolenic acid (ALA), an omega-3 fatty acid abundantly present in linseed, which becomes incorporated into intramuscular fat and muscle phospholipids (Villora et al. 2025). The enhanced lipid deposition contributes to the production of omega-3-enriched functional poultry meat without adversely affecting other proximate components. Similar increases in meat fat content and omega-3 fatty acid deposition following dietary flaxseed supplementation have been reported earlier by Betti et al. (2009) and Alagawany et al. (2022). Overall, the results suggest that dietary inclusion of linseed up to 10% level increases the fat fraction of broiler chicken meat while maintaining its moisture, protein, and mineral composition, thereby improving the nutritional value of the meat without compromising its overall quality.

Dietary supplementation of linseed up to the level of 10% had no significant effect ($P > 0.05$) on the sensory characteristics of either breast or thigh meat, indicating that enrichment of broiler chicken diets with linseed did not adversely influence consumer acceptability of meat. Sensory scores for acceptability, desirability, flavour, juiciness, tenderness, and colour remained consistently high across all treatment groups, demonstrating that the inclusion of linseed maintained the desirable eating quality of broiler chicken meat. Although slight numerical reductions in sensory scores were observed at higher inclusion levels (7.5–10%), these differences were not statistically significant and all scores remained within the "liked very much" category, suggesting excellent consumer acceptance. The absence of undesirable flavour or colour changes indicates that dietary linseed

levels up to 10% did not adversely affect the sensory attributes despite increasing the fat content of the meat. Similar findings have been reported by Cortinas et al. (2005), Betti et al. (2009), Rymer and Givens (2005), and Bhattarai et al. (2026), who observed that moderate dietary flaxseed supplementation improved the nutritional quality of broiler chicken meat without significantly affecting flavour, juiciness, tenderness, colour, or overall acceptability. Therefore, the present findings demonstrate that linseed can be incorporated into broiler chicken diets up to the levels of 10% without having any adverse effects on sensory quality and acceptability of broiler chicken meat.

5. Conclusions

The present study concluded that dietary linseed supplementation up to 10% level is safe for broiler chickens. Linseed inclusion on broiler chicken diets significantly altered haematological and serum biochemical parameters without adversely affecting the indicators of liver and kidney functions. It also maintained the physicochemical, textural, and sensory properties of broiler chicken meat, with 5% linseed inclusion level resulting in better numerical overall consumer acceptance score. Hence, dietary linseed can be suggested as a potential functional feed ingredient for broiler chicken nutrition to maintain chicken meat quality and favourably influence the haematological and serum biochemical parameters.

Declarations

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