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Research Article

Canarium Parvum Leaf Essential Oil Supplemented in the Diet of Japanese Quails: effect on Growth Performance, Nutrient Digestibility, Immune and Haematological Parameters

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Abstract

A 30 days study was carried out to determine the effect of dietary supplementation of *Canarium parvum* essential oil on the growth performance, nutrient digestibility, haematological and immune parameters of Japanese quails. A total of 150 2 weeks old Japanese quails (mixed sex) were randomly divided into five groups each with 50 birds. Each treatment group was further sub-divided in to five groups each with 10 chicks of comparable group weight. Standard diet (Corn-soya meal-based diet) was formulated according to the nutritional requirement for quails recommended by Nutritional Research Council (1994). A completely randomized design was adopted and birds in group A was fed standard diet only (control) while those in group B, C, D and E received standard diet supplemented with *Canarium parvum* essential oil at 200 mg, 400 mg, 600 mg and 800 mg per kg diet. Quails had unlimited access to fresh water and feed. Average daily weight gain and average daily feed intake were higher in birds fed *Canarium parvum* essential oil (B, C, D and E) comparedto control (group A) ($p<0.05$). Dry matter, crude protein, crude fibre, ether extract and nitrogen free extract digestibility were higher among birds in group B, C, D and E compared to A ($p<0.05$). Immunoglobulin A, G and M, protein and energy utilization were influenced ($p<0.05$) by the treatment. Lipase count ranged from 28.59 - 36.71 ng/mL, amylase (181.3 - 238.9 ng/mL), amylase (0.97 to 1.45 ng/mL), energy intake (2814.8 - 2937.37 ME/kcal/bird) and protein intake (222.34 - 232.12 g/bird) were affected. Hematocrit, red blood cell, hemoglobin and total leucocyte count were significantly different ($p<0.05$) among the groups. However, their values were within the established range for quails. It was concluded that *Canarium parvum* essential oil is rich in multiple bioactive compounds and can be supplemented in the diet of quails without compromising their performance and health state.

Key Words: antimicrobial; broilers, growth; performance; heamatology; phyto-components

Introduction

As the poultry industry shifts away from the widespread use of antibiotics for growth promotion, there is need to adopt other techniques to provide a safe supply of animal protein (meat and eggs) for consumers while maintaining high standards of animal health and welfare (John, 2024c; Musa et al., 2020). Essential oils is significantly gaining global interest because they are safe, eco-friendly and has no withdrawal period due to the presence of bioactive compounds (phytochemicals) (John, 2024b; Adewale et al., 2021). They volatile compounds that can be extracted from different parts of plants (seeds, leaves, flowers, bud and stem bark) and its composition can be influenced by age of plants, species, extraction method and geographical location (Singh et al., 2022; Ojediran et al., 2024). Among the potential essential oils with numerous phyto-constituents and medicinal properties are those from *Canarium parvum* leaves.

Canarium parvum is an evergreen shrub that belongs to the family Burseraceae and can grow between 120 – 150 feet tall (Thang et al., 2014; Thang et al., 2004). The genus Canarium are made up of 120 species spread across tropical Africa and some parts of Asia including India (Gurusamy et al., 2020; Nagawa et al., 2015). The tree's branch is about 3 – 5 mm in diameter while its pinnate leaves are alternately arranged with 2 to 4 pairs of leaflets (Tahir et al., 2021; Guo et al., 2009). The leaves, stems and roots of *Canarium parvum* are rich in tannins, flavonoids, alkaloids, saponins, terpenoids amongst others which have therapeutic properties such as, antioxidant, antimicrobial, immune-modulatory, hypoglycemia, hypocholesterolemia, hepatoprotective, gastro-protective, cytotoxic, antifungal, antiviral, antimicrobial, analgesics, anti-heminthic, antidiabetic, anti-ulcer and antidiarrheal properties (Giang et al., 2006; Galovicova et al., 2020). Ethno-medically, aqueous extract from *Canarium parvum* leaves can be used extensively in the treatment of skin infection, stomach ache, fever,

hepatitis, jaundice, cirrhosis, the elimination of intestinal parasites (Okhale et al., 2019; Dongmo et al., 2010). The essential oil from *Canarium parvum* leaves can inhibit the growth of *Salmonella spp, Escherichia coli, Staphylococcus spp, Aspergillus spp* and *Streptococcus spp* (Engonga et al., 2012)

Scientific studies have shown that essential oils can influence intestinal microbiota, increased digestibility and nutrient absorption, improvement of the immune response, morphological and histological modifications of the gastrointestinal tract and antioxidant activity (Shittu et al., 2023; Muritala et al., 2022). It also has strong capability for scavenging superoxide radicals, hydrogen peroxide and nitric oxide from activated macrophages, reducing iron complex and inhibiting lipid peroxidation (Alagbe, et al., 2022; Adewale et al., 2021). However, most of the result obtained are inconsistent, disparity in findings could be attributed to the type or part of medicinal plant used for essential oil extraction, compatibility with other feed ingredients as well as level of supplementation in diet. Therefore, this study was carried out to determine the effect of dietary supplementation of *Canarium parvum* essential oil on the growth performance, nutrient digestibility, haematological and immune parameters of Japanese quails.

Materials and methods

Experimental location

The experiment was carried out at the Poultry unit at Sumitra Research Institute, Gujarat India. Management of experimental birds were done according to the guidelines recommended and approved by the ethics committee at the Department of Animal Management, Sumitra Research Institute, Gujarat with Reference number AH08/2023/SG.

Sourcing of *Canarium parvum* essential oil and analysis of their bioactive compounds

Essential oil from the leaf of *Canarium parvum* was sourced from Medix Laboratory in Gujarat, India in the month of October, 2024. 20 mL of the purchased oil was sent to the Department of Biochemistry, Sumitra Research Institute, Gujarat, India for the analysis of bioactive compounds. Characterization and quantification of bioactive compound was carried out according to the procedure recently published by Alagbe et al. (2022). Shimadzu -Triple Quad Gas Chromatography and Mass Spectrometry (GC/MS) was used for the analysis. Machine was operated according to the manufacturer's recommendation.

Management of birds, duration and experimental design

A total of 150 2 weeks old Japanese quails (mixed sex) were purchased from Singh commercial poultry farms in Gujarat. Upon arrival, average weight of birds was recorded using a digital sensitive scale before it individually weighed and randomly divided into five groups each with 50 birds. Each treatment group was further sub-divided in to five groups each with 10 chicks of comparable group weight. Galvanized battery cage which was earlier disinfected with Morigad Active® was equipped with washed manual plastic feeders and drinkers. Cages measuring 200 cm by 180 cm by 100 cm to accommodate 10 birds was placed in an open sided pen. Birds were given a mixture of glucose and water-soluble vitamin (1:1) for the first 2 days out of their seven weeks acclimatization period. Standard diet (Corn-soya meal-based diet) was formulated according to the nutritional requirement for quails recommended by Nutritional Research Council (1994) was offered to birds thrice a day at 6:30 AM, 11:30 AM and 16:30 PM. The chicks were vaccinated against Newcastle disease and Gumboro on the 11th and 18th day respectively. Clean water was offered restricted and the entire experimental period was 30 days. Chicks in group A were fed standard diet without essential oil, those in group B, C, D and E received standard diet supplemented with essential oil at 200 mg, 400 mg, 600 mg and 800 mg in that order. A completely randomized design model was adopted and all other management practices were strictly adhered to. Proximate composition of standard diet was done according to the methods outlined by AOAC (2000).

Data Collection

Production Performance

Weight was taken weekly per replicate before feeding in the morning with a digital sensitive scale. Final body weight was taken at the end of the experiment.

Body weight gain was estimated as: final body weight - initial body weight

Average daily weight gain was computed by dividing the body weight gain by the total experimental period (in days).

Total feed consumption was determined by difference between the feed served and the feed refused on a daily basis.

Average daily feed consumption = Total feed consumption divided by the experimental period in days.

Feed conversion ratio was determined by dividing the average feed consumed by the average body weight gain.

Mortality was recorded as occurred and expressed in percentage at the end of experimental period.

$$\text{Protein intake (g/bird)} = \frac{\text{Crude protein in feed} \times \text{feed consumption}}{100}$$

$$\text{Energy intake (ME/Kcal/bird)} = \frac{\text{Metabolizable energy in feed} \times \text{feed consumption}}{1000}$$

$$\text{Protein Utilization} = \frac{\text{Crude protein intake (g/bird)}}{\text{Body weight gain (g/bird)}}$$

$$\text{Energy Utilization} = \frac{\text{Energy Intake (ME/Kcal/bird)}}{\text{Body weight gain (g/bird)}}$$

Digestibility trial

On the last day of the trial, 3 birds were randomly selected per replicate for digestibility trial. Birds were transferred to a labeled metabolic cage. Digestibility trial was carried out on the birds for seven days, the first two days was used as an acclimatization period, while the remaining five days was used to collect results. A known quantity of feed was fed to each bird and the droppings voided from each replicate was weighed and recorded. Wet droppings collected from each replicate was oven dried at 60 ℃ for 48 hours to determine their dry matter. At the end of the trial, droppings from each replicate were bulked together and samples were sent to the laboratory for further analysis. Proximate components were determined using near Vicon® infra-red analyzer (Mode 2ED, Netherlands). Nutrient digestibility was computed using the formula: -

$$\text{Nutrient Digestibility} = \frac{\text{Nutrient in feed} - \text{Nutrient in droppings}}{\text{Nutrient in feed}} \times 100$$

Evaluation of Intestinal digestive enzymes

On the 30th day of the experiment, 3 birds were randomly selected per replicate (from those used for nutrient digestibility) by severing the jugular vein with a sharp knife. Intestinal content was collected in a sterile sample bottle and sent to the Department of Microbiology, Sumitra Research Institute, Gujarat, India. Analysis of Lipase, Amylase and Protease was carried out using Retel® Mico-enzyme Analyzer (Model: TGH008, China).

Evaluation of Haematological and Immune parameters

At the end of the experiment, 2 mL of blood was collected from the wing vein of 3 randomly selected birds per replicate (from those used for nutrient digestibility trial) into labeled sample bottles with anticoagulant. Collection was carried out early in the morning and samples were placed in an ice pack to prevent deterioration before it was sent to the laboratory for further analysis. Immunoglobulin A, G and M were determined using Velox Immuno Assay® (Model RX23, China) while haematocrit, red blood cell, hemoglobin and total leucocyte count were examined using Sysmex automated blood analyzer (Model 230D, China).

Data analysis

Data obtained on growth performance, nutrient digestibility, digestive enzyme count and haematological parameters were analyzed using General Linear Model procedures of Statistical Analysis System (SAS, version 9.1.3 of 2007). Differences in mean were computed using Duncan's Multiple Range Test for multiple comparisons. Significance was determined at $p < 0.05$.

Experimental Results

Ingredient and chemical composition of experimental diet is presented in Table 1. Standard diet contains: crude protein (23.02 %), crude fibre (3.41 %), ether extract (4.01 %), calcium (1.16 %), phosphorus (0.43 %) and energy (2910.6 Kcal/kg).

Ingredients	Content
Maize	55.71
Corn gluten meal	7.11
Soya meal	30.4
Fish meal	2.12
Dicalcium phosphate	2.5
Limestone	0.88
L-Lysine	0.3
DL-Methionine	0.35
Premix	0.25
Toxin binder	0.03
Sodium chloride	0.35
Total	100
Determined analysis (%)	
Crude protein	23.02
Crude fibre	3.41
Ether extract	4.01
Calcium	1.16
Phosphorus	0.43
Energy (MEkcal/kg)	2910.6

Table 1: Ingredient and chemical composition of experimental diet

Vitamin and Mineral premix Each 2.5 kg consist of: Vit A 15,000, 000 IU; Vit D3, 3000, 000 IU; Vit. E. 15g; Vit k3 6 g; Vit B1, 2000 mg; Vit B2, 90g; Vit B6, 200 g; Vit B12, 20 mg; Pantothenic acid, 50 g; Niacin, 70 g, Folic acid, 1500 mg; Biotin, 70 g; Choline Chloride, 600 mg, Fe, 50 g; Mn, 100 g; Cu, 3 g; Co, 200 mg; Si, 150 mg and Zn, 55 g

Bioactive compounds in *Canarium parvum* leaf essential oil (Table 2). The major bioactive compound are α-Caryophyllene (31.86 %), Limonene (10.82 %), Linalool (9.11 %), β-Copaene (7.92 %), Phytol (5.92 %), β-Chamigrene (5.57 %), Humulene (4.80 %), Isophytol (3.55 %), Cadalene (3.04 %), Sesquithujene (2.69 %), β-Selinene (2.50 %), α-Bulnesene (2.45 %), β-Calacolene (2.39 %), Hexadecadienal (2.20 %), Pentadecanol (2.06 %), β-Isocomene (1.95 %), 3-Methyl Hexane (1.85 %), 2,6-trimethyl-1-cyclohexane (1.60 %), 16, Octadecanal (1.54 %) and α-Gurjenene (1.33 %).

Table 3, displays the growth performance of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil. Body weight gain was lower among birds that received treatment A (163.32 g/b) than in treatment B (232.63 g/b), group C (233.52 g/b), group D (234.09 g/b) and group E (236.05 g/b) ($p<0.05$). Total feed consumption was higher among birds fed treatment E (1009.2 g/b), treatment D (1008.1 g/b), group C (1005.6 g/b), group B (1000.1 g/b) than in treatment A (967.1 g/b). There is an improvement in feed conversion ratio of quails fed diet supplemented with *Canarium parvum* relative to those in group A ($p<0.05$). Protein and energy intake values varied from 222.43 - 232.12 g/bird and 2814.84 to 2937.37 MEkcal/bird) were higher in treatment E, D, C and E than in treatment 1 ($p<0.05$). Protein utilization (0.10 - 0.14); energy utilization (12.33 - 17.82) were influenced by the treatment ($p<0.05$).

Nutrient digestibility of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil is presented in Table 4. Dry matter digestibility value varied from 76.95 - 82.55 %, crude protein (67.69 - 76.68 %), crude fibre (39.98 to 42.07 %), ether extract (48.07 to 55.33 %) and nitrogen free extract (58.09 - 68.94 %) were higher among birds which received treatment B, C, D and E compared to treatment A ($p<0.05$).

Intestinal digestive enzymes of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil (Table 5). Population of lipase, amylase and protease in the intestine was higher in treatment B (35.07 ng/mL; 233.8 ng/mL; 1.39 ng/mL), treatment C (35.11 ng/mL; 235.1 ng/mL; 1.40 ng/mL), treatment D (36.05 ng/mL; 238.4 ng/mL; 1.42 ng/mL), treatment E (36.71 ng/mL; 238.9 ng/mL; 1.45 ng/mL) than in treatment A (28.59 ng/mL; 181.3 ng/mL; 0.97 ng/mL) ($p<0.05$).

Immune parameters of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil is displayed in Table 6. Values of Immunoglobulin A, G and M were lower in treatment A (1.85 mg/dl; 0.85 mg/dl; 2.23 mg/dl) than in treatment B (2.20 mg/dl; 1.71 mg/dl; 3.01 mg/dl), treatment C (2.21 mg/dl; 1.76 mg/dl; 3.05 mg/dl), treatment D (2.25 mg/dl; 1.85 mg/dl; 3.31 mg/dl) and treatment E (2.33 mg/dl; 1.98 mg/dl; 3.32 mg/dl).

Haematological indices of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil (Table 7). Hematocrit count varied from 25.72 - 32.23 %, red blood cell [(1.91 - 3.11 ($\times 10^{12}$/L)], hemoglobin (6.75 - 11.18 g/dL) and total leucocytes [(14.65 - 21.15 ($\times 10^{9}$/L)]. Parameters

obtained were higher in treatment C, D and E, intermediate in treatment B and lower in treatment A ($p<0.05$).

Compounds	Retention time (min)	% Area
Phytol	6.04	5.95
Limonene	6.73	10.82
Isophytol	7.90	3.55
Pentadecanol	8.11	2.06
Cadalene	8.25	3.04
β-Chamigrene	8.76	5.57
α-Caryophyllene	9.57	31.86
Linalool	10.10	9.11
α-Bulnesene	10.47	2.45
β-Calacolene	11.21	2.39
Humulene	11.69	4.80
Hexadecadienal	11.85	2.20
Sesquithujene	12.82	2.69
β-Selinene	12.55	2.50
β-Copaene	13.09	7.92
β-Isocomene	13.28	1.95
16, Octadecanal	13.50	1.54
α-Gurjenene	14.12	1.33
2,6-trimethyl-1-cyclohexane	15.37	1.60
3-Methyl Hexane	16.02	1.85

Table 2: Bioactive compounds in *Canarium parvum* leaf essential oil

Variables	A	B	C	D	E	SEM	P-value
Initial body weight (g/b)	67.18	66.97	67.08	67.11	67.55	5.63	0.02
Final body weight (g/b)	230.5^{b}	299.6^{a}	300.6^{a}	301.2^{a}	303.6^{a}	41.77	0.04
Body weight gain (g/b)	163.32^{b}	232.63^{a}	233.52^{a}	234.09^{a}	236.05^{a}	39.55	0.03
Average daily weight gain (g/b)	5.44^{b}	7.75^{a}	7.78^{a}	7.80^{a}	7.87^{a}	1.44	0.01
Total feed consumption (g/b)	967.1^{b}	1000.1^{a}	1005.6^{a}	1008.1^{a}	1009.2^{a}	165.3	0.05
Average daily feed consumption (g/b)	32.23^{b}	33.34^{a}	33.52^{a}	33.60^{a}	33.64^{a}	2.61	0.02
Feed conversion ratio	5.92^{a}	4.31^{b}	4.31^{b}	4.31^{b}	4.28^{c}	1.02	0.03
Mortality (%)	1.30	-	-	-	-	0.05	0.001
Protein intake (g/bird)	222.43^{b}	230.02^{a}	231.29^{a}	231.86^{a}	232.12^{a}	44.06	0.06
Protein utilization	0.14^{a}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}	0.08	0.01
Energy intake MEkcal/bird)	2814.84^{b}	2910.89^{a}	2926.89^{a}	2934.17^{a}	2937.37^{a}	207.6	0.09
Energy utilization	17.82^{a}	12.51^{b}	12.46^{b}	12.43^{b}	12.33^{b}	1.94	0.02

Table 3: Growth performance of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil Values followed by different letters were significantly different ($p<0.05$); Group A: Standard diet only (control); Group B: Standard diet with 200 mg *Canarium parvum* leaf essential oil per kg diet; Group C: Standard diet with 400 mg *Canarium parvum* leaf essential oil per kg diet; Group D: Standard diet with 600 mg *Canarium parvum* leaf essential oil per kg diet; Group E: Standard diet with 800 mg *Canarium parvum* leaf essential oil per kg diet; SEM: standard error of mean

Parameters	A	B	C	D	E	SEM	P-value
Dry matter	76.95^{b}	81.11^{a}	82.08^{a}	82.12^{a}	82.55^{a}	19.19	0.05
Crude protein	67.69^{b}	75.22^{a}	76.02^{a}	76.11^{a}	76.68^{a}	18.45	0.04
Crude fibre	39.98^{b}	41.08^{a}	41.76^{a}	41.87^{a}	42.07^{a}	8.11	0.02
Ether extract	48.07^{b}	55.02^{a}	55.11^{a}	55.18^{a}	54.33^{a}	12.00	0.03
Nitrogen free extract	58.09^{b}	67.46^{a}	67.55^{a}	68.09^{a}	68.94^{a}	17.22	0.04

Table 4: Nutrient digestibility of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil Values followed by different letters were significantly different ($p<0.05$); Group A: Standard diet only (control); Group B: Standard diet with 200 mg *Canarium parvum* leaf essential oil per kg diet; Group C: Standard diet with 400 mg *Canarium parvum* leaf essential oil per kg diet; Group D: Standard diet with 600 mg *Canarium parvum* leaf essential oil per kg diet; Group E: Standard diet with 800 mg *Canarium parvum* leaf essential oil per kg diet; SEM: standard error of mean

Parameters (ng/mL)	A	B	C	D	E	SEM	P-value
Lipase	28.59[b]	35.07[a]	35.11[a]	36.05[a]	36.71[a]	11.50	0.04
Amylase	181.3[b]	233.8[a]	235.1[a]	238.4[a]	238.9[a]	32.11	0.03
Protease	0.97[b]	1.39[a]	1.40[a]	1.42[a]	1.45[a]	0.03	0.01

Table 5: Intestinal digestive enzymes of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil Values followed by different letters were significantly different ($p<0.05$); Group A: Standard diet only (control); Group B: Standard diet with 200 mg *Canarium parvum* leaf essential oil per kg diet; Group C: Standard diet with 400 mg *Canarium parvum* leaf essential oil per kg diet; Group D: Standard diet with 600 mg *Canarium parvum* leaf essential oil per kg diet; Group E: Standard diet with 800 mg *Canarium parvum* leaf essential oil per kg diet; SEM: standard error of mean

Variables (mg/dl)	A	B	C	D	E	SEM	P-value
IgA	1.85[b]	2.20[a]	2.21[a]	2.25[a]	2.33[a]	0.05	0.01
IgG	0.85[b]	1.71[a]	1.76[a]	1.85[a]	1.98[a]	0.03	0.01
IgM	2.23[b]	3.01[a]	3.05[a]	3.31[a]	3.32[a]	0.06	0.02

Table 6: Immune parameters of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil Values followed by different letters were significantly different ($p<0.05$); Group A: Standard diet only (control); Group B: Standard diet with 200 mg *Canarium parvum* leaf essential oil per kg diet; Group C: Standard diet with 400 mg *Canarium parvum* leaf essential oil per kg diet; Group D: Standard diet with 600 mg *Canarium parvum* leaf essential oil per kg diet; Group E: Standard diet with 800 mg *Canarium parvum* leaf essential oil per kg diet; SEM: standard error of mean

Variables	A	B	C	D	E	SEM	P-value
Hematocrit (%)	25.72[c]	28.80[b]	31.98[a]	32.00[a]	32.23[a]	10.22	0.03
Red blood cell ($\times 10^{12}$/L)	1.91[c]	2.07[b]	3.00[a]	3.02[a]	3.11[a]	0.04	0.01
Hemoglobin (g/dL)	6.75[b]	9.02[b]	10.55[a]	11.15[a]	11.18[a]	5.12	0.01
Total leucocytes ($\times 10^{12}$/L)	14.65[b]	18.70[b]	20.93[a]	21.06[a]	21.15[a]	7.93	0.02

Table 7: Haematological indices of Japanese quails fed diet supplemented with *Canarium parvum* leaf essential oil Values followed by different letters were significantly different ($p<0.05$); Group A: Standard diet only (control); Group B: Standard diet with 200 mg *Canarium parvum* leaf essential oil per kg diet; Group C: Standard diet with 400 mg *Canarium parvum* leaf essential oil per kg diet; Group D: Standard diet with 600 mg *Canarium parvum* leaf essential oil per kg diet; Group E: Standard diet with 800 mg *Canarium parvum* leaf essential oil per kg diet; SEM: standard error of mean

Discussion

Bioactive compounds in essential oils have pharmacological or therapeutic properties such as, anti-inflammatory, cytotoxic, antioxidant, antifungal, antiviral, immune-stimulatory, anticancer, antidiarrheal, anti-helminthic, cardio-protective, gastro-protective, anti-radical activities amongst others (Ojediran et al., 2024a, b; Omokore and Alagbe et al, 2022). These compounds are non-toxic, effective and has no withdrawal period (Alagbe, 2023; John, 2024c). Result obtained in this experiment is in agreement with the reports of Nguyen et al. (2023). The high concentrations of α-Caryophyllene (31.86 %) and Limonene (10.82 %) in *Canarium parvum* leaf essential oil suggests that it possess anti-inflammatory (Klavina et al., 2015), anticancer, antioxidant (Alagbe et al., 2022; Agubosi et al., 2022), fragrance and antibacterial properties (Karthika and Paulsamy, 2014). Simlai and Roy (2012); Edeoga et al. (2005) reported that phytol, isophytol, cadalene, humulene, linalool and pentadecanol have antidiarrheal activity, anti-inflammatory, cytotoxic and immune-stimulatory. β-Chamigrene α-Bulnesene and β-Calacolene present in *Canarium parvum* leaf essential oil is reported to have anemiagenic, antimicrobial activity and anticancer activity (John, 2024a; John, 2024b). Hexadecadienal, 3-methyl hexane, 2, 6-trimethyl-1-cyclohexane have been reported to have antimicrobial (Singh et al., 2022; Adewale et al., 2021) and anti-helminthic activity (Odozi et al., 2014; Aworinde et al., 2016). β-Selinene, β-Copaene, Sesquithujene, β-Isocomene, 16, Octadecanal and α-Gurjenene have antimicrobial activity (Sharma, 2012; Gawali and Jadhav, 2011) and anti-inflammatory (Bazie et al., 2014), 5α reductase inhibitor, cardio-protective activity (Nester et al., 2002; Olajuyige et al., 2011).

Results on average daily weight gain showed that birds fed diet supplemented with *Canarium parvum* leaf essential oil (treatment B, C, D and E) were higher compared to the control (treatment A) suggesting that bioactive compounds in the oil have digestion stimulating properties due to the stimulation of enzymes (lipase, amylase and protease) and is also capable of protecting intestinal morphology and permeability, thus increasing the absorption of nutrients (John, 2024e; Musa et al., 2020). The result obtained is in agreement with the reports of Ahmad et al. (2016) when botanical extracts and oil was supplemented in the diet of laying hens. Similarly, average daily feed consumption improved among birds which received *Canarium parvum* leaf essential oil relative the control. This result indicates that the essential oil had positive influence on the smell and taste of feed causing the birds to eat more. Result obtained is in agreement with the reports of Daniel et al. (2023) when pawpaw seed oil was supplemented in the diet of broiler chicken. However, this result is contrary to the outcome obtained by John (2024d) who recorded a non-significant difference in average feed consumption of quails fed *Megaphrynium macrostachyum* leaves. The variation in results could be attributed to the level of supplementation in diet as well as composition of bioactive compounds (Omokore and Alagbe, 2019). No mortality was recorded among birds fed essential oil suggesting that it is capable of killing pathogenic organisms thereby altering the competition for nutrients. The antimicrobial properties of *Canarium parvum* leaf essential oil also reduce intestinal inflammation by pathogens, thereby improving immunity in birds. Results obtained is in consonance with the reports of Cross et al. (2007) when herbs were supplemented in the diet of broilers. The balanced intestinal flora of quails fed diet supplemented with essential oil causes the production of more nutrients thus energy becomes available for growth and body metabolism (Gerzilov et al., 2015; Guo et al., 2004a).

Canarium parvum leaf essential oil demonstrated immune-modulatory properties by improving immunoglobulin A, G and M counts of quails. This result shows that supplementing the oil in the diets of birds can promote phagocytosis at any site of infection in the body, thus inhibiting the activities of pathogens in the gut (Bravo et al., 2014). The result obtained aligns with the findings of El-Soud (2000) when quails were fed diet containing Nigella sativa seed preparation. Antibodies are immunoglobulins that are produced

by birds in response to specific antigens to neutralize toxins and bacteria cells (John, 2024c; Alagbe, 2022.

Haematological values could serve as reference information for comparison in conditions of nutrient deficiency, physiology and health status of animals (Daramola et al., 2005; Isaac et al., 2013). The hematocrit count recorded in this study is within 25.00 - 36.00 % reported by Abou-Elkhair et al. (2014) when some medicinal plants were fed to birds. Decrease in hematocrit count could be a sign of lungs and renal disease (John, 2024b). Hemoglobin and red blood cell were within reference range (6.00 - 15.00 g/dL); [(1.90 - 5.00 ($\times 10^{12}$/L)] reported by RAR (2009). Low hemoglobin level suggests insufficient oxygen in the tissues of birds while low red blood cell is a sign of anaemia (Omokore and Alagbe, 2019; Fallah and Mirazeai, 2016). Total leucocyte count is within the baseline value [(12.00 - 25.00 ($\times 10^{9}$/L)] reported by RAR (2009). White blood cell is responsible for the production of antibodies to protect the body against disease and infections (John, 2024c; Alagbe, 2024a).

Conclusion

In conclusion, *Canarium parvum* leaf essential oil has a wide range of medicinal properties in birds due to the presence of bioactive compounds which have a proven record of safety, efficacy, eco-friendly and no withdrawal period. The oil can be supplemented up to 600 mg/per kg diet without causing any detrimental effect on the growth and health state of Japanese quails.

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