



## Effects of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) supplementation on reproductive performance, embryogenesis, physiological parameters and oxidative stress in Japanese quails

**Goodness Nkankeya\***

MSc

Nasarawa State University  
911019, Nasarawa State, Keffi, Nigeria  
<https://orcid.org/0009-0005-0898-8767>

**Ibrahim Musa-Azara**

PhD

Nasarawa State University  
911019, Nasarawa State, Keffi, Nigeria  
<https://orcid.org/0000-0001-5496-9026>

**Kingsley Omogiade Idahor**

PhD

Nasarawa State University  
911019, Nasarawa State, Keffi, Nigeria  
<https://orcid.org/0000-0003-0544-6127>

**Abstract.** The aim of this research was to scrutinise the influence of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) supplementation on embryogenesis, physiological parameters and oxidative stress of Japanese quails. Four dietary treatments were used consisting of a control diet and diets enriched with garlic, ginger, and their combination. A total number of 180 laying birds were randomly allocated to the four treatments consisting of 3 replicates with 15 birds per replicate. Four hundred and eighty eggs were collected for embryogenesis study after the birds had been on the experimental diets for four weeks. Data were analysed using one-way analysis of variance (ANOVA) in SPSS. Fertility percentage and reproductive capacity significantly increased in the treated groups

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\*Corresponding author ([nkankeya@gmail.com](mailto:nkankeya@gmail.com))



while a combination of ginger and garlic resulted in higher percentage of hatchability of fertile eggs. All treatments culminated in a significant increase in crown-rump length ( $P < 0.05$ ) while embryonic weights were similar for all treatments. Significant improvement was recorded in total antioxidant capacity of birds administered ginger, garlic, and a concomitant use of ginger and garlic although oxidative stress index values were statistically indistinguishable across all treatments ( $P > 0.05$ ). Serum level of IgG was improved following treatment with garlic ( $P < 0.05$ ). Whereas the serum level of IgE was significantly elevated as a result of ginger administration while a combination of ginger and garlic resulted in elevated levels of IgM ( $P < 0.05$ ). Total cholesterol decreased significantly due to the combination of ginger and garlic. Combination of ginger and garlic also resulted in improved haematological parameters. Garlic administration elicited a significant increase ( $P < 0.05$ ) in total protein while other parameters were similar. So, ginger and garlic positively influenced fertility, embryonic growth-related traits, immunity and antioxidant defence in Japanese quails, supporting their use as safe natural feed additives

**Keywords:** phytogetic additive; hatchability; humoral immunity; antioxidant capacity; lipid metabolism; haematology; serum biochemistry

## Introduction

Sustainable production of healthy poultry birds that is not detrimental to consumers' health have been of great concern in recent years. Various studies have increasingly focused on natural feed additives, such as phytochemicals, to enhance bird performance, immunity, and overall physiological well-being. N. Aminullah *et al.* (2025) reported that because of concerns about antimicrobial resistance and food safety, phytochemical feed additives (PFAs) have become increasingly considered sustainable alternatives to antibiotic feed additives in poultry production. This could have resulted as a response to human requests for more natural food and the cost implications of these antibiotics. According to N. Abdelli *et al.* (2021), PFAs, also called phytochemicals, are natural plant-based substances added to animal feed without harming the animals. They improve gastrointestinal health, systemic function, productivity, and welfare, while reducing morbidity and mortality. PFAs also provide antioxidant and immune support, and combining them can lower inclusion

levels, reduce feeding costs, and enhance overall results compared with single additives.

G. Dosu *et al.* (2023) reported that ginger (*Zingiber officinale* Roscoe) is widely used as a natural feed additive due to its rich bioactive compounds, including gingerols, shogaols, gingerdione, and phenolic ketones. It has antioxidant, anti-inflammatory, and immunomodulatory properties, supporting animal health and disease resistance. Additionally, ginger improves cellular function, lipid metabolism, and digestion, enhancing nutrient absorption, growth performance, and feed efficiency. As a phytochemical additive, it offers a sustainable alternative to synthetic growth promoters and antibiotics. W.A. Abd El-Ghany (2024) noted that garlic, as a natural feed additive, contains bioactive compounds such as allicin, diallyl sulphides, alliin, saponins, phenols, amino acids, vitamins, minerals, and essential oils, providing antioxidant, antimicrobial, anti-inflammatory, and immune-modulating effects. In poultry, garlic is used in powder, extract, oil, or commercial supplement forms to improve blood

parameters, enhance immunity, reduce infections, and alleviate heat stress.

Scientists O.E. Oke *et al.* (2025) described Japanese quails (*Coturnix japonica*) as small poultry birds majorly reared for both meat and egg production and currently gaining increasing attention in the poultry industry due to their rapid growth, early maturity, and high egg-laying ability, with the ability to begin egg production at about 40–42 days of age and annual production of over 200 eggs per bird under proper management. Distinguished by their small body size, efficient feed conversion, low maintenance requirement and relatively hardy and resistant to many common poultry diseases, makes them easy to manage and suitable for small-scale and backyard farming systems. As reported by A.F. Abdul-Majeed & S.Y. Abdul-Rahman (2022) ginger prevented the effects of oxidative stress and most of the biochemical values were the same as in the control group in H<sub>2</sub>O<sub>2</sub>-induced oxidative stress research, significantly increasing glutathione 2.92 µmol/l while the value of the stress index (malondialdehyde 0.41 nmol/ml) were reduced signifying a deduction in harmful free radical that can cause cell damage when elevated thus concluded that ginger have the ability to improve blood parameters and serum antioxidants status. Research by Z. Nemati *et al.* (2021) using 240 laying quails reported that Ginger root Powder administered at different doses reduced blood triglyceride levels though was not effective on blood total antioxidant capacity and malondialdehyde.

Researchers M.I Abo-Samaha & H.A. Basha (2021) evaluated the effect of garlic oil spray before the inception of incubation and continuing its application for the first 10 days in incubator showed that at 2% of the garlic solution spray and reported remarkable hatchability increases of the fertile Japanese quail. A study by W.M. Dosoky *et al.* (2024) on 300 quails fed a cadmium-contaminated diet showed a

significant reduction in immunoglobulin, especially IgM. Supplementation with vitamin C (200 mg/kg), dried garlic powder (500 mg/kg), or their combination improved IgM and IgG levels, mitigating cadmium's harmful effects. This demonstrates the detoxifying and immune-boosting properties of garlic and vitamin C. Nevertheless, there is still limited research on inclusion level, embryogenesis, antioxidant status, serum immunoglobulins, and blood parameters in Japanese quail under local production conditions. Thus, this research is aimed to help bridge this knowledge gap, ensuring data-driven recommendations that could enhance both the productivity and the product quality using natural feed additives, and ensuring safe consumption.

The aim of this study was to evaluate the effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on embryogenesis, physiological parameters and oxidative stress of Japanese quail. Specifically, the objectives were to:

- ◆ evaluate the effects of dietary ginger, garlic, and their combination on fertility, hatchability, reproductive capacity, and embryonic development of Japanese quails;
- ◆ assess the effects of dietary ginger, garlic, and their combination on antioxidant status and serum immunoglobulin responses;
- ◆ examine the effects of dietary ginger, garlic, and their combination on lipid profile, haematological indices, and serum biochemical parameters.

## Materials and Methods

The experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus. The study area lies within the Guinea Savanna zone of North Central Nigeria and is located at latitude 08°35'N and longitude 08°33'E. The study was conducted using a Completely Randomised Design. A total of 180

laying Japanese quails were used for this research. The birds were randomly assigned to 4 dietary treatments, each replicated 3 times, giving 45 birds per treatment and 15 birds per replicate. Treatment 1, which is the control, contained neither ginger nor garlic. Treatment 2 was fed 20 g of ginger per kg of feed. Treatment 3 was fed 20 g of garlic per kg of feed, whereas Treatment 4 was fed 20 g each of ginger and garlic per kg of feed. The feeding trial lasted for 8 weeks.

The experimental birds were sourced from the National Veterinary Research Institute, Vom, Plateau State. Upon arrival, the birds were kept for 4 weeks before the inception of the feeding trial to allow for adequate acclimatisation and rest. All procedures were conducted in accordance with the ARRIVE guidelines (n.d.) and approved ethical standards for the care and use of animals in research. The birds were housed in battery cages inside the teaching and research farm facility. Before stocking, the cages and pens were washed, disinfected, and allowed to dry for a week. Adequate ventilation, lighting, and strict biosecurity were maintained throughout the experiment. Birds had ad libitum access to clean water and experimental diets. Fresh garlic bulbs and ginger rhizomes were purchased from a local market, cleaned, sliced, air-dried, and ground into powder before incorporation into the experimental diets.

A total of 480 eggs were collected after four weeks of dietary treatment and incubated under standard incubation conditions. Fertility, hatchability, reproductive capacity, embryonic weight, and crown-rump length were evaluated during the incubation period. Embryogenesis was evaluated during the incubation period using measurements of embryonic weight and crown-rump length. On days 5, 10, and 15 of incubation, selected eggs were carefully opened and embryos were removed for embryonic measurements. Embryonic weight was measured

using a digital weighing balance, while crown-rump length was measured in millimetres using a digital Vernier calliper. Morphological observations, including feather development and visible abnormalities, were also recorded.

Fertility percentage was calculated using the formula:

$$\text{Fertility (\%)} = \frac{\text{Number of fertile eggs}}{\text{Total eggs set}} \times 100, \quad (1)$$

where *Number of fertile eggs* = eggs that showed evidence of embryonic development after candling or egg break-out examination; *Total number of eggs set* = total number of eggs placed in the incubator for hatching. Hatchability percentage was calculated using the formula:

$$\text{Hatchability (\%)} = \frac{\text{Number of hatched chicks}}{\text{Total fertile eggs}} \times 100, \quad (2)$$

where *Number of hatched chicks* = total number of chicks successfully hatched from fertile eggs; *Total number of fertile eggs* = eggs confirmed fertile during incubation assessment.

Reproductive capacity percentage was calculated using the formula:

$$\text{Reproductive capacity (\%)} = \frac{\text{Number of hatched chicks}}{\text{Total eggs set}} \times 100, \quad (3)$$

where: *Number of hatched chicks* = total number of chicks successfully produced from the eggs set; *Total number of eggs set* = total number of eggs incubated during the experiment. Fertility percentage was used to evaluate the proportion of eggs that were fertile after incubation. Hatchability percentage was used to determine the proportion of fertile eggs that successfully hatched, while reproductive capacity percentage was used to assess the overall efficiency of chick production from the total eggs incubated.

Total oxidative stress was determined using the automated colorimetric method described by O. Erel (2005). In this assay, oxidant molecules in the serum oxidise the ferrous

ion-o-dianisidine complex to ferric ions, which then react with xylenol orange in an acidic medium to produce a coloured complex. The intensity of the colour formed was measured spectrophotometrically and was proportional to the total oxidant concentration of the sample. Total antioxidant capacity was determined using an ABTS-based spectrophotometric assay according to O. Erel (2004). Antioxidants present in the sample reduce the pre-formed ABTS radical cation, causing decolourisation of the blue-green chromophore. The decrease in absorbance was measured spectrophotometrically and was proportional to the antioxidant capacity of the sample. Results were expressed as Trolox equivalent antioxidant capacity.

Serum immunoglobulins IgG, IgM, and IgE were determined using the sandwich enzyme-linked immunosorbent assay technique. Blood samples were allowed to clot and were centrifuged at 3,000 rpm for 15 min to obtain serum. Serum samples were added into microplate wells pre-coated with antibodies specific to the immunoglobulin of interest. Enzyme-linked secondary antibodies were then added, followed by a chromogenic substrate after incubation. The reaction was stopped and absorbance was measured at 450 nm using a microplate reader. Immunoglobulin concentrations were obtained from a standard calibration curve based on the ELISA principle of E. Engvall & P. Perlmann (1971). Total cholesterol, triglycerides, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol were determined using Randox® kits following standard enzymatic colorimetric procedures and the manufacturer's instructions. Low-density lipoprotein cholesterol was calculated using the Friedewald formula (4) (Friedewald et al., 1972):

$$LDL-C = TC - HDL-C - (TG/2.2), \quad (4)$$

where *LDL-C* = low-density lipoprotein cholesterol, *TC* = total cholesterol, *HDL-C* = high-

density lipoprotein cholesterol, *TG* = triglycerides, the factor 2.2 was used because lipid concentrations were expressed in mmol/L.

Blood (2 mL) was collected into K<sub>3</sub>-EDTA anticoagulant tubes for haematological analysis. Packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count were determined. Packed cell volume was measured by the microhematocrit method, haemoglobin concentration by the cyanmethemoglobin method, while red and white blood cell counts were estimated using a hemocytometer as described by S.M. Lewis et al. (2011).

Serum samples were analysed for total protein, albumin, urea, and creatinine using a Vita lab Selectra E clinical chemistry analyser according to the manufacturer's standard analytical procedures. Total protein was determined by the biuret method, albumin by the bromocresol green method, urea by the urease – Berthelot reaction, and creatinine by the Jaffe reaction. The analyser measured absorbance and automatically converted the readings to concentrations based on the instrument calibration settings.

Data on hatchability, embryogenesis, oxidative stress markers, serum immunoglobulins, lipid profile, serum biochemical parameters, and haematological parameters were subjected to one-way analysis of variance (ANOVA) in SPSS version 25. Treatment means were separated using Duncan's multiple range test, and significance was declared at  $P < 0.05$  (Duncan, 1955):

$$Y_{ij} = \mu + T_i + e_{ij}, \quad (5)$$

where  $Y_{ij}$  = individual observation,  $\mu$  = overall mean,  $T_i$  = effect of the *i*th dietary treatment, and  $e_{ij}$  = random experimental error.

## Results and Discussion

The effects of dietary garlic, ginger, and their combination on reproductive performance, embryogenesis, oxidative stress, serum

immunoglobulins, lipid profile, and haematological and biochemical parameters of Japanese quails were evaluated. Values are presented as mean ± standard deviation, with significant differences indicated at  $P < 0.05$ . Table 1 presents the effects of dietary garlic, ginger, and their combination on fertility, hatchability, and reproductive capacity of Japanese quails. Fertility percentage differed significantly among

treatments ( $P < 0.05$ ), with the garlic-supplemented and combined ginger-garlic groups showing higher fertility values than the control group. Hatchability of fertile eggs was not significantly affected by dietary treatments ( $P > 0.05$ ). Reproductive capacity significantly increased in the supplemented groups, particularly in birds administered the combined ginger-garlic diet.

**Table 1.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on fertility and hatchability of Japanese quail

Parameter	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	P-value
Fertility (%)	88.00 ± 4.00 <sup>b</sup>	90.67 ± 10.07 <sup>b</sup>	94.67 ± 2.31 <sup>a</sup>	93.33 ± 6.11 <sup>a</sup>	0.041*
Hatchability (FE, %)	91.11 ± 7.36 <sup>a</sup>	90.09 ± 11.02 <sup>a</sup>	88.77 ± 4.79 <sup>a</sup>	92.85 ± 2.43 <sup>a</sup>	0.612 <sup>ns</sup>
Reproductive Capacity (%)	80.00 ± 4.00 <sup>b</sup>	81.33 ± 10.07 <sup>b</sup>	84.00 ± 4.00 <sup>ab</sup>	86.67 ± 6.11 <sup>a</sup>	0.048*

**Note:** means with different superscripts (a, b) differ significantly at  $P < 0.05$ ; mm = millimetres; g = grams; NS = not significant; \* – significant

**Source:** authors' experimental data

Table 2 shows the effects of dietary garlic, ginger, and their combination on embryonic development of Japanese quails. Crown-rump length significantly increased in all supplemented groups compared with the control group ( $P < 0.05$ ),

indicating enhanced embryonic growth. However, embryonic weight did not differ significantly among treatments ( $P > 0.05$ ), suggesting that dietary supplementation mainly influenced embryonic linear growth rather than embryo mass.

**Table 2.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on embryogenesis of Japanese quail

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
Crown-Rump Length (mm)	24.09 ± 0.99 <sup>b</sup>	28.19 ± 1.01 <sup>a</sup>	28.18 ± 0.98 <sup>a</sup>	28.22 ± 1.11 <sup>a</sup>	0.0002*
Embryonic Weight (g)	1.01 ± 0.02	1.32 ± 0.14	1.27 ± 0.12	1.25 ± 0.11	0.8533 <sup>ns</sup>

**Note:** means with different superscripts (a, b) differ significantly at  $P < 0.05$ ; mm = millimetres; g = grams; NS = not significant; \* – significant

**Source:** authors' experimental data

Table 3 presents the effects of dietary garlic and ginger supplementation on oxidative stress markers of Japanese quails. Total antioxidant capacity significantly increased in the supplemented groups, especially in birds fed ginger and the ginger-garlic combination diets ( $P < 0.05$ ).

Total oxidant status also varied significantly among treatments, while oxidative stress index values were not significantly different ( $P > 0.05$ ). These findings suggest that dietary supplementation improved antioxidant responses without causing marked oxidative imbalance.

**Table 3.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on antioxidant capacity and total oxidative stress of Japanese quails

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
TAC (mmol/L)	244.94 ± 12.45 <sup>c</sup>	308.47 ± 4.32 <sup>a</sup>	287.83 ± 10.31 <sup>b</sup>	311.57 ± 2.41 <sup>a</sup>	0.0001*
TOS (μmol/mL)	2.73 ± 0.19 <sup>c</sup>	3.19 ± 0.14 <sup>b</sup>	4.07 ± 0.05 <sup>a</sup>	3.35 ± 0.84 <sup>b</sup>	0.0044*
OSI	0.01 ± 0.00	0.00 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.0594 <sup>ns</sup>

**Note:** means with different superscripts (a, b, c) differ significantly at  $P < 0.05$ ; TAC = total antioxidant capacity, TOS = total oxidant status, OSI = oxidative stress index, mmol/L = millimoles per litre, μmol/mL = micromoles per millilitre, NS = not significant; \* – significant

**Source:** authors' experimental data

Table 4 shows the effects of dietary supplementation on serum immunoglobulin concentrations of Japanese quails. Significant differences were observed among treatments for IgG, IgM, and IgE levels ( $P < 0.05$ ). Garlic

supplementation improved IgG concentration, while the combined ginger-garlic treatment produced the highest IgM values. Ginger supplementation resulted in elevated IgE concentration compared with other treatments.

**Table 4.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on the serum level of immunoglobulin of Japanese quails

Parameter (g/L)	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
IgG	6.00 ± 0.40 <sup>a</sup>	5.13 ± 0.15 <sup>b</sup>	7.77 ± 0.38 <sup>a</sup>	5.97 ± 0.04 <sup>b</sup>	0.0023*
IgM	1.04 ± 0.08 <sup>c</sup>	0.87 ± 0.09 <sup>c</sup>	1.20 ± 0.06 <sup>b</sup>	2.23 ± 0.012 <sup>a</sup>	0.0000*
IgE	2.00 ± 0.06 <sup>b</sup>	3.33 ± 0.18 <sup>a</sup>	2.17 ± 0.09 <sup>b</sup>	1.47 ± 0.07 <sup>c</sup>	0.0000*

**Note:** means with different superscripts (a, b, c) differ significantly at  $P < 0.05$ ; IgG = immunoglobulin G; IgM = immunoglobulin M; IgE = immunoglobulin E; \* – significant

**Source:** authors' experimental data

Table 5 presents the effects of dietary supplementation on lipid profile of Japanese quails. Total cholesterol significantly decreased in birds administered the combined ginger-garlic diet compared with the control group ( $P < 0.05$ ). High-density lipoprotein cholesterol

improved in supplemented groups, while low-density lipoprotein cholesterol and triglyceride concentrations were reduced, especially in garlic-treated birds. These findings indicate improved lipid metabolism following dietary supplementation.

**Table 5.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on Lipid profile of Japanese Quail

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
TC (mmol/L)	3.73 ± 0.12 <sup>ab</sup>	3.30 ± 0.15 <sup>b</sup>	3.57 ± 0.09 <sup>c</sup>	2.97 ± 0.03 <sup>a</sup>	0.0139*
HDL (mmol/L)	1.06 ± 0.03 <sup>b</sup>	1.27 ± 0.03 <sup>a</sup>	1.07 ± 0.09 <sup>b</sup>	1.30 ± 0.06 <sup>a</sup>	0.0328*
LDL (mmol/L)	1.47 ± 0.09 <sup>a</sup>	1.60 ± 0.06 <sup>a</sup>	0.99 ± 0.07 <sup>b</sup>	1.40 ± 0.06 <sup>a</sup>	0.0321*
TG (mmol/L)	1.40 ± 0.06 <sup>a</sup>	1.60 ± 0.06 <sup>a</sup>	0.99 ± 0.09 <sup>b</sup>	1.40 ± 0.06 <sup>a</sup>	0.0019*

**Note:** means with different superscripts (a, b, c) differ significantly at  $P < 0.05$ ; TC = total cholesterol; HDL = high-density lipoprotein; LDL = low-density lipoprotein; TG = triglycerides; \* – significant

**Source:** authors' experimental data

Table 6 shows the effects of dietary garlic and ginger supplementation on haematological parameters of Japanese quails. Packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count differed significantly among treatments

( $P < 0.05$ ). The combined ginger-garlic treatment produced the highest values for packed cell volume, haemoglobin concentration, and red blood cell count, suggesting improved oxygen-carrying capacity and physiological status of the birds.

**Table 6.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on haematological parameters of Japanese quails

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	P-value
PCV (%)	34.66 ± 0.88 <sup>b</sup>	31.00 ± 0.58 <sup>c</sup>	34.00 ± 0.57 <sup>b</sup>	39.67 ± 0.88 <sup>a</sup>	0.0003*
Hb (g/dL)	10.87 ± 0.72 <sup>b</sup>	9.73 ± 0.21 <sup>c</sup>	11.03 ± 0.37 <sup>b</sup>	12.26 ± 0.12 <sup>a</sup>	0.0024*
RBC (×10 <sup>12</sup> /L)	3.31 ± 0.07 <sup>b</sup>	3.08 ± 0.02 <sup>c</sup>	3.43 ± 0.07 <sup>b</sup>	3.92 ± 0.08 <sup>a</sup>	0.000*
WBC (×10 <sup>9</sup> /L)	10.37 ± 1.94 <sup>b</sup>	9.33 ± 5.04 <sup>b</sup>	13.30 ± 1.73 <sup>a</sup>	14.00 ± 0.58 <sup>a</sup>	0.003*

**Note:** means with different superscripts (a, b, c) differ significantly at  $P < 0.05$ ; PCV – packed cell volume; Hb – haemoglobin; RBC – red blood cells; WBC – white blood cells; \* – significant

**Source:** authors' experimental data

Table 7 shows the serum biochemical parameters of Japanese quails across the different treatments. There are significant differences at  $P < 0.05$  among treatments for total protein, globulin, urea, creatinine, sodium (Na<sup>+</sup>), and potassium (K<sup>+</sup>), while albumin did not differ significantly among treatments ( $P > 0.05$ ). Total protein values were highest in Treatments 1 and 3, while Treatment 2 recorded the lowest value. Globulin concentration was highest in

Treatment 1 and lowest in Treatment 3. Urea levels were highest in Treatment 2 and lowest in Treatment 3, whereas creatinine concentration was highest in Treatment 3 and lowest in Treatment 1. Sodium (Na<sup>+</sup>) concentration was highest in Treatment 3, with Treatments 1, 2, and 4 showing similar values and no significant differences among them. Potassium (K<sup>+</sup>) concentration was highest in Treatment 4 and lowest in Treatment 2.

**Table 7.** Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on serum biochemical parameters of Japanese quails

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	P-value
Total protein (g/L)	53.00 ± 1.53 <sup>a</sup>	41.33 ± 1.45 <sup>c</sup>	59.00 ± 0.58 <sup>a</sup>	45.33 ± 0.88 <sup>b</sup>	0.0004*
Albumin (g/L)	20.67 ± 0.88	19.00 ± 0.58	22.67 ± 1.45	21.67 ± 0.88	0.1388 (NS)
Globulin (g/L)	31.33 ± 0.09 <sup>a</sup>	22.67 ± 0.09 <sup>b</sup>	15.75 ± 0.12 <sup>c</sup>	22.87 ± 0.09 <sup>b</sup>	0.0001*
Urea (mmol/L)	2.13 ± 0.08 <sup>b</sup>	3.17 ± 0.09 <sup>a</sup>	1.75 ± 0.12 <sup>c</sup>	2.28 ± 0.09 <sup>b</sup>	0.0001*
Creatinine (µmol/L)	38.67 ± 0.88 <sup>c</sup>	55.33 ± 2.73 <sup>b</sup>	63.00 ± 1.53 <sup>a</sup>	53.00 ± 0.58 <sup>b</sup>	0.0000*
Na <sup>+</sup> (mmol/L)	152.00 ± 1.50 <sup>b</sup>	148.00 ± 1.53 <sup>b</sup>	158.33 ± 1.20 <sup>a</sup>	152.00 ± 0.58 <sup>b</sup>	0.0047*
K <sup>+</sup> (mmol/L)	5.87 ± 0.08 <sup>ab</sup>	5.70 ± 0.06 <sup>b</sup>	5.90 ± 0.06 <sup>ab</sup>	6.13 ± 0.12 <sup>a</sup>	0.0414*

**Note:** means with different superscripts (a, b, c) within the same row differ significantly at  $P < 0.05$ ; NS = not significant; \* – significant

**Source:** authors' experimental data

The significant improvement in fertility percentage observed in garlic- and ginger-supplemented groups suggests that these phyto-genic additives may support reproductive efficiency and embryo viability in Japanese quails. The higher fertility values recorded in the garlic and combined ginger-garlic groups may be associated with the antioxidant and antimicrobial properties of the bioactive compounds present in these additives, particularly allicin in garlic and gingerols in ginger, which may improve physiological stability and reproductive function. However, hatchability of fertile eggs was not significantly affected among treatments, although numerically higher values were observed in the combined supplementation group. This indicates that while supplementation may improve fertilisation and embryo survival, it may not necessarily influence the final hatching process under the present experimental conditions. The improved reproductive capacity recorded in the supplemented groups further supports the beneficial role of garlic and ginger in enhancing overall reproductive output. Similar findings were reported by M.M.A. El-Kashef & M.I. El Sabry (2025), who observed that the use of ginger and garlic solutions affected embryonic development, hatchability, blood parameters and post-hatch performance in Japanese quails. The significant increase in crown-rump length observed in all supplemented groups indicates that dietary garlic and ginger supported embryonic growth and development during incubation. This effect may be attributed to the antioxidant properties of the phyto-genic compounds, which could help reduce oxidative damage during embryogenesis and support proper tissue development. Although embryonic weight numerically increased in supplemented groups, the differences were not statistically significant, suggesting that supplementation mainly influenced embryonic linear growth rather than embryo

mass accumulation. Enhanced nutrient utilisation and improved physiological conditions during incubation may also have contributed to the observed increase in crown-rump length. The improvement in crown-rump length recorded in the present study is supported by M.M.A. El-Kashef & M.I. El Sabry, who reported that ginger and garlic solutions influenced embryonic development and hatchability traits in Japanese quail. The significant increase in total antioxidant capacity recorded in birds fed ginger, garlic, and their combination indicates enhanced antioxidant defence following dietary supplementation. Ginger contains bioactive compounds such as gingerols, shogaols, and phenolic derivatives, while garlic contains sulphur-containing compounds including allicin and diallyl sulphides, all of which possess antioxidant properties capable of scavenging free radicals and reducing oxidative damage. The higher total antioxidant capacity observed particularly in the ginger and combined supplementation groups suggests improved ability of the birds to neutralise reactive oxygen species. Although total oxidant status varied significantly among treatments, oxidative stress index values did not differ significantly, indicating that oxidant and antioxidant activities remained relatively balanced.

These findings agree with those of B. Sevim (2026) reported that fermented black garlic powder supplementation improved antioxidant status, immune response, serum parameters, and performance-related traits in Japanese male quails. The significant differences observed in serum immunoglobulin concentrations indicate that dietary garlic and ginger supplementation influenced immune responsiveness in Japanese quails. Garlic supplementation resulted in higher IgG concentration, while the combined ginger-garlic treatment produced the highest IgM values, suggesting enhanced humoral immune activity. The

elevated IgE concentration observed in the ginger group may reflect stimulation of immune responsiveness by the phytochemical compounds present in ginger. The immunomodulatory effects observed in this study may be linked to the antioxidant and antimicrobial activities of garlic and ginger bioactive compounds, which could enhance antibody production and improve immune function. The improvement in serum immunoglobulin concentrations observed in the present study agrees with B. Sevim, who reported that fermented black garlic powder supplementation improved immune response and serum parameters in Japanese male quails. M. Fathi *et al.* (2025) also found that black garlic powder influenced immunoglobulin protein levels, haematological indicators and antioxidant capacity in broiler chickens.

The reduction in total cholesterol and triglyceride concentrations observed in supplemented birds suggests improved lipid metabolism following garlic and ginger administration. The combined ginger-garlic treatment produced the lowest total cholesterol values, while garlic supplementation significantly reduced low-density lipoprotein cholesterol and triglycerides. These responses may be associated with the ability of garlic and ginger bioactive compounds to regulate lipid synthesis and fat metabolism. The improvement in high-density lipoprotein concentration observed in supplemented groups may further indicate beneficial effects on lipid transport and metabolism. The reduction in total cholesterol, triglycerides and low-density lipoprotein cholesterol observed in the supplemented groups agrees with C.A. Mbajjorgu *et al.* (2025), who reported that garlic influenced lipid profiles in laying quails. Similarly, M.M. El-Kashef (2022) reported improved blood biochemical responses in quail birds fed ginger. The improvement in packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count

observed in the combined ginger-garlic group suggests improved physiological and haematopoietic status of the birds. Higher packed cell volume and haemoglobin concentration may indicate improved oxygen-carrying capacity and better physiological condition, while increased red blood cell count may suggest enhanced erythropoiesis. The elevated white blood cell count observed in garlic-supplemented and combined-treatment groups may reflect improved immune responsiveness and physiological adaptation following phytochemical supplementation. These findings indicate that garlic and ginger supplementation did not exert adverse effects on blood formation and may instead support normal haematological function. Similar observations were reported by O.I. Olayinka *et al.* (2024), who found that garlic meal influenced haematological parameters and serum biochemical responses in Japanese quails. The variations observed in serum biochemical parameters indicate that dietary garlic and ginger supplementation influenced protein metabolism, nitrogen metabolism, and electrolyte balance in Japanese quails. Garlic supplementation produced the highest total protein concentration, which may suggest improved protein synthesis, nutrient utilisation, or physiological stability. The differences observed in globulin concentration may also reflect altered immune-related protein metabolism among treatments. Urea and creatinine concentrations varied significantly among groups, although the values remained within acceptable physiological ranges, suggesting no obvious adverse effect of supplementation on kidney function. The significant differences observed in sodium and potassium concentrations indicate that the dietary treatments may have influenced electrolyte regulation and metabolic balance. The variations observed in serum biochemical parameters are consistent with the report by O.I. Olayinka *et al.* that

garlic meal affected that garlic meal affected serum biochemical parameters in Japanese quails and M.M. El-Kashef (2022) also reported that ginger supplementation influenced blood biochemical responses in quail birds.

## Conclusions

The findings of this study demonstrated that dietary supplementation with ginger, garlic, and their combination positively influenced the reproductive performance, embryogenesis, antioxidant status, immune response, lipid profile, haematological indices, and serum biochemical parameters of Japanese quails. Fertility percentage and reproductive capacity were significantly improved ( $P < 0.05$ ) in the supplemented groups compared with the control group, although hatchability percentage was not significantly affected among treatments ( $P > 0.05$ ). Embryonic crown-rump length significantly increased ( $P < 0.05$ ) in birds fed diets containing ginger and garlic, indicating improved embryonic growth and development, whereas embryonic weight showed no significant difference among treatments.

The antioxidant results revealed significant increases ( $P < 0.05$ ) in total antioxidant capacity in supplemented groups, particularly in birds administered ginger and the combined ginger-garlic diets. Total oxidant status varied significantly among treatments, while oxidative stress index values remained relatively stable, suggesting maintenance of oxidative balance. Significant improvements ( $P < 0.05$ ) were also observed in serum immunoglobulin concentrations, indicating enhanced humoral immune response in supplemented birds.

Also, the dietary supplementation significantly improved ( $P < 0.05$ ) haematological parameters including packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count, reflecting improved physiological and immune status of the birds. Serum biochemical and lipid profile analyses showed significant reductions ( $P < 0.05$ ) in total cholesterol, triglycerides, and low-density lipoprotein cholesterol, while beneficial effects were also observed on protein metabolism and electrolyte balance.

In conclusion, the study confirmed that ginger and garlic, particularly when combined at 20 g per kg of feed each, can serve as effective natural PFAs for improving reproductive performance, physiological stability, antioxidant defence, and health status of Japanese quails. Further studies should evaluate the effects of dietary ginger and garlic supplementation on the growth performance, survivability, physiological status, immune response, and post-hatch development of chicks produced from supplemented Japanese quail breeders. The combined supplementation of ginger and garlic showed improved overall physiological responses, and it is recommended as a nutritional strategy for improving the health and productivity of Japanese quails.

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## Conflict of Interest

None.

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**Вплив введення часнику (*Allium sativum*)  
та імбиру (*Zingiber officinale*) на репродуктивні показники,  
ембріогенез, фізіологічні параметри  
та оксидативний стрес у японських перепелів**

**Гуднес Нканкея**

Магістр

Університет штату Насарава

911019, штат Насарава, м. Кеффі, Нігерія

<https://orcid.org/0009-0005-0898-8767>

**Ібрагім Муса-Азара**

Доктор філософії

Університет штату Насарава

911019, штат Насарава, м. Кеффі, Нігерія

<https://orcid.org/0000-0001-5496-9026>

**Кінгслі Омогіаде Ідахор**

Доктор філософії

Університет штату Насарава

911019, штат Насарава, м. Кеффі, Нігерія

<https://orcid.org/0000-0003-0544-6127>

**Анотація.** Метою цього дослідження було вивчити вплив введення часнику (*Allium sativum*) та імбиру (*Zingiber officinale*) на ембріогенез, фізіологічні параметри та оксидативний стрес у японських перепелів. Використовувалися чотири раціони: контрольний та раціони, збагачені часником, імбиром та їх комбінацією. Загалом 180 несучих птахів були випадково розподілені на чотири групи з трьома повтореннями по 15 птахів у кожному. Було зібрано 480 яєць для дослідження ембріогенезу після чотиритижневого періоду годування експериментальними раціонами. Дані аналізувалися методом однофакторного дисперсійного аналізу (ANOVA) у SPSS. Відсоток заплідненості та репродуктивна здатність значно підвищилися у японських перепелів, що отримували добавки, а комбінація імбиру та часнику забезпечила вищий відсоток вилуплення життєздатних яєць. Усі обробки призвели до значного збільшення довжини «crown-rump» ( $P < 0,05$ ), тоді як вага ембріонів залишалася подібною у всіх групах. Значне покращення спостерігалось у загальній антиоксидантній здатності птахів, які отримували імбир, часник або їх комбінацію, хоча показники індексу оксидативного стресу статистично не відрізнялися між групами ( $P > 0,05$ ). Рівень IgG у сироватці підвищився після застосування часнику ( $P < 0,05$ ), тоді як рівень IgE значно підвищився після введення імбиру, а комбінація імбиру та часнику сприяла підвищенню рівня IgM ( $P < 0,05$ ). Загальний холестерин значно знизився у сироватці крові японських перепелів, що отримували комбінацію імбиру та часнику. Комбінація імбиру та часнику також покращила гематологічні показники. Введення часнику спричинило значне підвищення ( $P < 0,05$ ) у сироватці крові вмісту загального білка, тоді як інші показники залишалися подібними. Отже, імбир та часник позитивно вплинули на заплідненість, ріст ембріонів, імунітет та антиоксидантний захист у японських перепелів, підтримуючи їх використання як безпечних природних кормових добавок

**Ключові слова:** фітогенна добавка; відсоток вилуплення; гуморальний імунітет; антиоксидантна здатність; метаболізм ліпідів; гематологія; біохімія сироватки