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**Research Article**

# Evaluation of triphala extract as a feed supplement for enhancing carcass and meat quality traits in japanese quail (*coturnix coturnix japonica*)

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## Abstract

This research was conducted to determine the effect of Triphala extract on the growth performance, carcass parameters and meat quality in Japanese quail (*Coturnix coturnix japonica*). In this study, 160 growing quail were divided into a control group (without Triphala extract) and treatment groups of four (4 replicates containing 10 quails in each). Commercial feed and the addition of varying concentrations of Triphala extract (TPHE) 0.1 g/kg, 0.2 g/kg, and 0.3 g/kg were used in the study. The feed intake was obtained higher in the TPHE supplemented groups as compare to no additives group ($P < 0.05$). The TPHE additive affected the live weight gain values during 0 to 6 week of the experiment. Live weight, hot carcass weight, cold carcass weight, carcass yield, and breast meat weight was positively influenced by the supplementation of TPHE as compare to no addition ($P<0.05$). Breast meat proximate composition data indicated that, DM, CP and ash content was influenced in case of TPHE group as compared to the control group ($P < 0.05$). Result of storage of breast meat at 4 °C indicated that, the pH and peroxide value was lower in the groups with TPHE as compared to without TPHE ($P < 0.05$). The performance, carcass characteristics, meat composition and quality parameters were obtained positive with supplementation of 0.2 g/kg and 0.3 g TPHE/kg in case of the Japanese quail. To sum up, Triphala extract could be used in Japanese quail diet to ensure better performance, carcass characteristics, meat composition and quality; and could be suggestive to other poultry species following further detail study.

## Introduction

There are different types of quail available in the different geographical location of the world. The Japanese quail (*Coturnix coturnix japonica*) is indigenous to Europe, northern Africa, and Asia. The Japanese quail has been identified as an economically sustainable and highly productive due to its resistance to diseases and rapid growth cycle (3 to 4 generations per year). This bird is considered the smallest of the poultry varieties in terms of meat production, which makes it simple to manage and accommodate a large number of birds in a small space. For these reasons, the Japanese quail has also become increasingly significant on a global scale for its utilization as experimental animal models in biological and genetic research (Vargas-Sánchez et al., 2019). As a result, coturniculture, or the raising of quail, is gaining popularity, including the commercialization of different quail species and quail derived products such as quail fresh or processed meat, fresh or frozen carcasses, fresh or pickled eggs. The carcass and meat of Japanese quail are obtained after the quail attain 35 to 42 d of age and a body weight of 165 to 300 g. Nevertheless, the data regarding the carcass or meat quality intended for processing in quail production is limited and the available data are lacking in precision. The integration and husbandry of quail production (feeding, breeding, housing, slaughtering, processing and marketing) is crucial for keeping carcass and meat quality, just like it is for other birds. During the first stage of production, an initiation and growth diet including a balanced combination of nutrients such as carbohydrates, amino acids, essential fatty acids, minerals, vitamins, and water is fed to animals. Common dietary sources used to meet the carbohydrate requirement include grains, such as corn, whereas earthworms, fish, and soybean meal are frequently used as a protein source. To enhance the quality of poultry meat, primarily influenced by oxidative stress, natural ingredients such as medicinal plants or their extracts, organic compounds (tocopherols), rosemary, green tea, tomato, and honey extracts have been included in poultry diets due to their beneficial antioxidant properties. Based on the above, the present research was designed on the inclusion of natural ingredients in the Japanese quail diet to highlight their effect on growth, carcass characteristics, and meat quality.

Different researches conducting on broiler meat quality, however, there is very little research on quail on natural feed additives on their meat and egg quality. Many of the phytobiotic potential medicinal plant are utilized as traditional purposes for solving human

related problems. Some of them could be utilized directly or as the byproducts after its primary use. There is a growing demand for plant-based natural additives, supplements, nature-based medicines, nutraceuticals, health products, pharmaceuticals, food supplements, cosmetics etc. Among variety of medicinal plants and their byproducts amlaki, hortoki, bohera, aloe, mint, kalmeg, kalogira, curcuma, turmeric, shimul, onion, garlic, and cardamom are well known in Bangladesh. Phyllanthus emblica, being a multi-purpose food, has a large number of benefits with its antioxidant, skin enhancing, hair enriching, and many more abilities for everyone. P. emblica is composed of Vitamin C which is a rich antioxidant agent, which makes it a powerful tool against a variety of conditions, including various types of cancer. One of the less discussed benefits of P. emblica is how it helps the body absorb calcium in a positive way. Calcium is a vital element of our bones, teeth, and nails, and it also contributes to the health of our hair. It can enhance metabolic activity of several nutrients. Terminalia chebula, commonly known as Haritaki, is a prevalent plant found in tropical regions, particularly in Bangladesh. For centuries, different parts of its body, including fruits, barks, and leaves have been used as the source of herbal medicine in this region. This plant is believed to be effective in treating fever and different diseases caused by bacterial and fungal organisms in humans (Dash, 1991). It is reported that the extracts of this plant are potent against the organisms causing dental carries (RAI & Joshi, 2009), and the aqueous extract of its fruit is effective against the Helicobacter pylori infection in humans (Malekzadeh et al., 2001).

Ethanolic extracts of Terminalia chebula fruits may serve as possible antibacterial agents (Pasha and Islam, 2021). Terminalia bellirica (Gaertn.) Roxb. (Family Combretaceae), referred to as 'Belleric myrobalan,' is a large deciduous tree indigenous to the Indian subcontinent, Nepal, Sri Lanka, and Southest Asia (Gupta et al., 2020). T. bellirica is associated with a range of pharmacological effects due to its various bioactive secondary metabolites, including alkaloids, flavones, lignans, tannins, phenols, terpenoids, glycosides, and saponins (Akter et al., 2019). Modern studies suggest that the various compounds in T. bellirica may be responsible for its acclaimed health benefits, such as antipyretic, antioxidant, anti-inflammatory, and immunomodulatory properties (Sharma et al., 2021; Al-Harrasi et al., 2022). T. bellirica components were proven to enhance macrophage activities and immune response in terms of free radical scavenging and reactive oxygen species neutralization (Gunasekar et al., 2019).

Triphala is a composite mixture of *Phyllanthus emblica, Terminalia chebula* and *Terminalia bellerica* used in popular traditional medicine for the treatment of many chronic diseases such as ageing, heart ailments, hepatic diseases etc. (Kaur et al., 2002; Naik et al., 2005). Triphala can be used as an inexpensive and nontoxic natural product for the prevention and treatment of diseases like antidiarrheal, refrigerant, diuretic, antidysenteric, nutritive, tonic, and demulcent, galactagogue, aphrodisiac and antispasmodic, where vascular endothelial growth factors A–induced angiogenesis is involved (Arora et al., 2003). In addition to that, instead of utilizing synthetic growth promoters Triphala as natural feed additive having pharmacological properties, antioxidative actions and bioactive potentiality can be utilized in quail nutrition. Where natural source feed additives can ensure better health, productivity as well as safe animal product like meat or egg with highly nutritional potency.

It is generally considered that appropriate utilization of medicinal plant can promote the status of health of human and animal. Triphala and its constituents are common ayurveda in Bangladesh especially for the human for its health promoting efficacy. However, it could be used in the animal diet as well, since natural plant materials are composed of primary and secondary bioactive compounds (Biradar et al., 2008; Singh et al., 2016; Bostami et al., 2017); hence, it was expected that a combination of medicinal plants would have synergistic effects on birds in the current study. Nevertheless, to the best of our knowledge very few studies have investigated the effects of single and combination of Triphala and its constituents on poultry nutrition to date. Instead of using synthetic growth promoters and immune-stimulants, feed additives with phytogenic potential formula Triphala might play important role for the development of functional feed additives for poultry nutrition through synergism to improve the performance, intestinal microflora, serum parameters, immunity and carcass quality. However, to the best of our knowledge limited studies have investigated the effects of Triphala and their constituents on poultry nutrition to date. It is expected that a combination of medicinal plants will have synergistic effects on poultry in the current study. Additionally, it is expecting to test Triphala efficacy for obtaining more potentiality on health and physiology. Therefore, the present study will be conducted to investigate the effects of Triphala (*Phyllanthus emblica, Terminalia belerica and Terminalia chebula*) on the growth performance, carcass characteristics, meat quality of quail. Thus, it was hypothesized that, Tiphala will exhibit its potency on safe and quality animal product like meat from poultry species.

## Materials and Methods

Japanese quail (*Coturnix coturnix japonica*) were used as experimental animal in the current study due to its smallest size and fast-growing rate. A total of 240 growing quails were obtained from reputed farm in Gazipur, Bangladesh. The experiment with animals was carried out at Livestock and Poultry Research Farm, Gazipur Agricultural University, Bangladesh. Laboratory studies were carried out in the Department of Animal Science and Nutrition, Faculty of Veterinary Medicine and Animal Science, Gazipur Agricultural University, Bangladesh.

### Arrangement of experiments

The experiment lasted for 42 days, during which feed and water were provided ad libitum. Commercial broiler chick starter feed, comprising 23% crude protein and 3100 kcal/kg metabolic energy, was utilized in the feeding of quails. Quails were provided with feed for duration of 6 weeks, in accordance with their nutritional requirements (NRC, 1994). The study comprised 4 treatment groups (4 replications with 10 birds in each group) containing 0 g/kg, 0.1 g/kg, 0.2 g/kg, and 0.3 g/kg Triphala extract (TPHE). Experimental birds (160) were randomly assigned to the treatments and replications according to Completely Randomized Design. Natural and artificial lighting was implemented for 24 hours. In the quail rearing room, the room temperature was maintained comfortable and controlled with a thermometer. The temperature was set at 32–33 °C in the first week with the thermostatic heater in the main machines, where the quails were placed, and in the following weeks, the temperature was lowered by 2–3 °C each week until it stabilized at 24–25 °C.

### Triphala extraction process

Triphala (*Phyllanthus emblica, Terminalia belerica,* and *Terminalia chebula*) was collected from the local market in Gazipur District, Bangladesh. The Triphala was washed and subsequently dried for 24 hours in a drying cabinet maintained at 60 °C to produce the extract. Completely dried Triphala was ground and performed extraction at varying concentrations of ethanol and water (70% ethanol: 30% water and 80% water: 20% ethanol). A 10 g sample of ground Triphala was utilized for each extraction step. The Triphala was dissolved using an orbital shaker at 500 RPM for 24 hours at 40 °C (Boeco, OS20, Hamburg, Germany). The dissolved mixture was further filtered through coarse filter paper, and ethanol was evaporated at 50 °C in a rotary evaporator to get the extract.

### Determination of growth performance

The weekly live weight gain of quails was computed by subtracting the previous week's average live weight from the average live weight of each replication in each group, indicating the weights for each week. Throughout the study, the live weights of the quails were measured individually using an electronic scale with a precision of ±0.01 g, on a weekly basis from the commencement of the research. The weekly live weight gains of quails were calculated by subtracting the average live weight of the previous week from the average live weight of each replication within each group determined in the weighting for each week. At the end of the trial (after 5 weeks), the average live weight value of each group (female and male separately) was assessed.

### Determination of carcass characteristics

Quails were deprived of food for 12 hours prior to the routine slaughtering procedure. The quail's wings, indicative of the average body weights of both male and female within each group, were collected from each repetition. The feet of the quails were removed and the weight of the warm carcass was ascertained following the extraction of the internal organs. The breast meat samples from each group were collected from the slaughtered quails, and their carcass characteristics were assessed. Following the measurement of organ weights, including thigh, breast, wings, back, and neck, the carcasses were stored at 4 °C for 24 hours, after which the cold carcass weight was recorded. Carcass yield was determined by evaluating the live weight and the cold carcass weight at the time of slaughter. Following the determination of the cold carcass weight, the weights of the main carcass parts (neck, back, thighs, breast, and wings) were measured using a scale with an accuracy of ±0.01 g, and the results were documented to ascertain their proportions within the carcass. The ratio of each carcass part was determined by proportioning the main carcass weights to the carcass weight.

### Meat quality analysis

Randomly selected birds from each replication of treatments were humanely slaughtered at the end of the experimental period. After slaughter, the meat samples were collected, processed, and preserved for various analyses. The proximate composition and oxidative stability of meat were analyzed using different meat samples processed separately.

### Meat proximate composition

The proximate composition of meat was analyzed following AOAC (2000) guidelines, whereas protein content, comprising glucidic molecules and their catabolites (0.25%), was determined by difference (Ouhayoun and Dalle Zotte, 1996). Methodology was applied following previous study (Bostami et al., 2018). After 2 weeks of storage, 10 quail breasts/treatment were allowed thawing for 12 h at +4°C, freed from polyethylene bags and individually ground with a Retsch Grindomix GM 200 (7000 g for 10 s). The degree of muscle lipid oxidation was assessed using a spectrophotometer (Hitachi U-2000; Hitachi, Mannheim, Germany) calibrated at 532 nm, which measured the absorbance of thiobarbituric acid-reactive substances along with a 1,1,3,3-tetraethoxypropane calibration curve (Botsoglou et al., 2004). Oxidation products were determined as malondialdehyde (MDA) equivalents (mg MDA/kg muscle).

### Measurement of meat pH

The pH of the meat sample was determined by homogenizing 5 g of raw meat with 25 ml of distilled water. Subsequent to homogenization, the homogenates were filtered, and the pH of each sample was assessed using a pH meter (Hanna, Romania) at ambient temperature (Jang et al. 2008). While measuring the pH value of the sample, the pH meter was calibrated for accuracy by assessing buffer solutions (pH = 4 and pH = 7) after every five measurements. The methodology was implemented in accordance with the prior study (Bostami et al., 2018).

### Peroxide value of breast meat

Initially, lipids were extracted from quail breasts, and nearly 5 g of the extract was added to a mixture of chloroform and methanol (1:1) that was homogenized until phase separation was achieved, as per the cold extraction methodology defined by Folch et al. (1957). The peroxide value was ascertained using the spectrophotometric method in accordance with the methodology of Semb (2012). A total of 2.5 mL of lipid extract, containing a minimum of 0.01 g of fat, was mixed with ammonium thiocyanate and ferrous chloride. The lipid extracts were analyzed using a UV-VIS spectrophotometer (MINGYI-Henan China) at 500 nm. A standard curve with varying concentrations of ferric chloride (FeCl3) (0, 12, 25, 50, 75, 100 µL) was utilized, and the results were reported in mmol O2/kg of material.

### Statistical Analysis

The Statistical Analysis System (SAS) software (2012) was used for the statistical evaluation involving all data collected at the end of the experiment by applying the variance analysis method. Significant differences between the groups were confirmed by Duncan's multiple range tests. Differences with $P < 0.05$ were regarded as significant (a, b) and $P < 0.10$ as tendency.

## Results

### Growth performance of quail

**Table 1:** Effect of supplementation of Triphala Extract on Growth performance of quail

| Parameters | Week | TPHE1 | TPHE2 | TPHE3 | TPHE4 | SEM | P-value |
|---|---|---|---|---|---|---|---|
| **Body weight (g)** | 0 | 8.47$^{a}$ | 8.48$^{a}$ | 8.46$^{a}$ | 8.45$^{a}$ | 0.02 | 0.748 |
| | 6 | 291.50$^{b}$ | 297.86$^{ab}$ | 301.98$^{a}$ | 303.44$^{a}$ | 2.27 | 0.014 |
| **Body weight gain (g)** | 0 to 3 | 145.80$^{a}$ | 154.83$^{a}$ | 156.03$^{a}$ | 154.67$^{a}$ | 3.61 | 0.242 |
| | 3 to 6 | 137.23$^{a}$ | 134.55$^{a}$ | 137.48$^{a}$ | 140.32$^{a}$ | 3.24 | 0.677 |
| | 0 to 6 | 283.03$^{b}$ | 289.38$^{ab}$ | 293.52$^{a}$ | 295.00$^{a}$ | 2.27 | 0.014 |
| **Feed intake (g)** | 0 to 3 | 323.52$^{c}$ | 340.39$^{b}$ | 343.88$^{a}$ | 342.83$^{a}$ | 0.44 | <0.0001 |
| | 4 to 6 | 687.49$^{b}$ | 692.87$^{ab}$ | 694.76$^{a}$ | 698.46$^{a}$ | 1.71 | 0.006 |
| | 0 to 6 | 1011.01$^{c}$ | 1033.27$^{b}$ | 1038.64$^{ab}$ | 1041.29$^{a}$ | 1.71 | <0.0001 |
| **FCR** | 0 to 3 | 2.23$^{a}$ | 2.20$^{a}$ | 2.21$^{a}$ | 2.22$^{a}$ | 0.05 | 0.989 |
| | 3 to 6 | 5.02$^{a}$ | 5.16$^{a}$ | 5.07$^{a}$ | 4.98$^{a}$ | 0.12 | 0.733 |
| | 0 to 6 | 3.58$^{a}$ | 3.57$^{a}$ | 3.54$^{a}$ | 3.53$^{a}$ | 0.03 | 0.613 |

$^{a, b, c}$ Different letters within the same row indicating significant differences at the level of $P < 0.05$. Where $P < 0.10$ indicating tendency of difference. SEM: Standard Error of Mean.

The dietary Triphala powder herbal extract (TPHE) did not influence initial body weight on day 0 ($P > 0.05$). By week 6, body weight and total body weight gain (0–6 weeks) were considerably elevated in birds administered TPHE3 and TPHE4 compared to the control group ($P < 0.05$). Feed consumption markedly elevated with increased TPHE levels during the study ($P < 0.05$). Nonetheless, the FCR was not substantially influenced by TPHE supplementation at any growth stage ($P > 0.05$), suggesting that the increased body weight was primarily linked to increase feed intake.

### Carcass characteristics of quail

**Table 2:** Effect of supplementation of Triphala Extract on carcass characteristics of quail

| Parameters | TPHE1 | TPHE2 | TPHE3 | TPHE4 | SEM | P-value |
|---|---|---|---|---|---|---|
| **Live Weight (g)** | 280.46$^{c}$ | 282.40$^{b}$ | 291.54$^{a}$ | 292.72$^{a}$ | 0.535 | <.0001 |
| **Hot Carcass Weight (g)** | 209.58$^{c}$ | 212.24$^{b}$ | 222.50$^{a}$ | 223.52$^{a}$ | 0.363 | <.0001 |
| **Cold Carcass Weight (g)** | 210.36$^{c}$ | 214.18$^{b}$ | 218.46$^{a}$ | 219.40$^{a}$ | 0.353 | <.0001 |
| **Carcass Yield (%)** | 73.46$^{d}$ | 74.26$^{c}$ | 74.94$^{b}$ | 75.44$^{a}$ | 0.093 | <.0001 |
| **Thighs (%)** | 32.90$^{a}$ | 33.80$^{a}$ | 34.28$^{a}$ | 34.63$^{a}$ | 0.545 | 0.179 |
| **Breast (%)** | 33.46$^{b}$ | 34.57$^{a}$ | 35.10$^{a}$ | 35.09$^{a}$ | 0.289 | 0.015 |
| **Wings (%)** | 9.38$^{a}$ | 9.25$^{a}$ | 9.44$^{a}$ | 9.65$^{a}$ | 0.236 | 0.687 |
| **Back (%)** | 14.43$^{a}$ | 14.62$^{a}$ | 15.31$^{a}$ | 15.45$^{a}$ | 0.414 | 0.297 |
| **Neck (%)** | 7.33$^{a}$ | 7.74$^{a}$ | 7.91$^{a}$ | 8.07$^{a}$ | 0.226 | 0.183 |

$^{a, b, c}$ Different letters within the same row indicating significant differences at the level of $P < 0.05$. Where $P < 0.10$ indicating tendency of difference. SEM: Standard Error of Mean.

The study consisted of 4 treatment groups containing 0 g/kg, 0.1 g/kg, 0.2 g/kg, and 0.3 g/kg Triphala extract (TPHE1, TPHE2, TPHE3 and TPHE4).

Table 2 shows the effect of Triphala extract on carcass characteristics of quail. Dietary Triphala powder herbal extract (TPHE) influenced the quail carcass attributes such as live weight, hot and cold carcass weights, and carcass yield ($P < 0.05$). TPHE3 and TPHE4 fed birds had better carcass performance than TPHE1 and TPHE 2. TPHE supplementation increased breast yield ($P = 0.015$) but did not influence thigh, wing, back, or neck proportions ($P > 0.05$). This suggests that greater TPHE levels increase carcass production and breast meat formation without changing carcass component distribution.

### Meat composition of quail

**Table 3:** Effect of supplementation of Triphala Extract on meat composition of quail

| Parameters | TPHE1 | TPHE2 | TPHE3 | TPHE4 | SEM | P-value |
|---|---|---|---|---|---|---|
| **Dry matter** | 26.71$^{a}$ | 25.45$^{bc}$ | 25.33$^{c}$ | 25.60$^{b}$ | 0.054 | <.0001 |
| **Protein** | 18.88$^{c}$ | 19.29$^{bc}$ | 20.12$^{b}$ | 21.62$^{a}$ | 0.275 | <.0001 |
| **Fat** | 4.60$^{a}$ | 4.34$^{a}$ | 4.30$^{a}$ | 3.77$^{a}$ | 0.334 | 0.404 |
| **Ash** | 0.96$^{b}$ | 1.60$^{a}$ | 1.66$^{a}$ | 1.56$^{a}$ | 0.038 | <.0001 |

$^{a, b, c}$ Different letters within the same row indicating significant differences at the level of $P < 0.05$. Where $P < 0.10$ indicating tendency of difference. SEM: Standard Error of Mean.

The study consisted of 4 treatment groups containing 0 g/kg, 0.1 g/kg, 0.2 g/kg, and 0.3 g/kg Triphala extract (TPHE1, TPHE2, TPHE3 and TPHE4).

The findings in Table 3 indicate that dietary supplementation with Triphala powder herbal extract (TPHE) markedly affected the proximate composition of quail meat. Dry matter, crude protein, and ash contents were significantly influenced ($P < 0.05$), while crude fat content was not affected by TPHE supplementation ($P > 0.05$).

### Meat pH value of quail

**Table 4:** Effect of supplementation of Triphala Extract on pH value of breast meat of quail

| Parameters | TPHE1 | TPHE2 | TPHE3 | TPHE4 | SEM | P-value |
|---|---|---|---|---|---|---|
| **pH 0d** | 6.119 | 6.179 | 6.111 | 6.169 | 0.089 | 0.934 |
| **pH 3d** | 5.863 | 5.686 | 5.756 | 5.704 | 0.054 | 0.149 |
| **pH 7d** | 5.643 | 5.501 | 5.539 | 5.519 | 0.065 | 0.443 |
| **pH 14d** | 5.494$^{a}$ | 5.246$^{b}$ | 5.308$^{ab}$ | 5.268$^{b}$ | 0.066 | 0.069 |
| **pH 21d** | 5.382 | 5.222 | 5.315 | 5.312 | 0.068 | 0.545 |

[a, b, c] Different letters within the same row indicating significant differences at the level of P < 0.05. Where P < 0.10 indicating tendency of difference. SEM: Standard Error of Mean.

The study consisted of 4 treatment groups containing 0 g/kg, 0.1 g/kg, 0.2 g/kg, and 0.3 g/kg Triphala extract (TPHE1, TPHE2, TPHE3 and TPHE4).

Across the storage period, a gradual decline in pH was observed in all the treatments, reflecting ongoing fermentation or biochemical changes. While early storage (0–7 days) showed no statistical differences, significant divergence among the dietary treatments (P>0.05). Nevertheless, the values were tended to be different at day 14 among the treatments (P<0.10). While during late storage period (day 21) there were no differences observed among the treatments (P>0.05). The results demonstrate that TPHE treatments did not influenced profoundly the pH dynamics during storage, particularly there were some tendency at day 14, which should be warranted through study. These findings indicate that TPHE inclusion did not play negative impact or role in modulating acidity and stability during the storage period.

### Peroxide value of breast meat of quail

**Table 5:** Effect of supplementation of Triphala Extract on peroxide value of breast meat (meq/kg) of quail

| Parameters | TPHE1 | TPHE2 | TPHE3 | TPHE4 | SEM | P-value |
|---|---|---|---|---|---|---|
| **PVM 0d** | 2.90[a] | 2.82[a] | 2.44[a] | 2.19[a] | 0.296 | 0.347 |
| **PVM 3d** | 5.63[a] | 4.02[b] | 3.68[bc] | 2.80[c] | 0.247 | <0.0001 |
| **PVM 7d** | 6.84[a] | 5.05[b] | 4.32[c] | 3.94[c] | 0.196 | <0.0001 |
| **PVM 14d** | 7.62[a] | 6.16[b] | 5.21[c] | 3.97[d] | 0.217 | <0.0001 |
| **PVM 21d** | 8.32[a] | 6.55[b] | 6.02[c] | 4.03[d] | 0.016 | <0.0001 |

PVM: Peroxide value of meat (meq/kg). [a, b, c] Different letters within the same row indicating significant differences at the level of P < 0.05. Where P < 0.10 indicating tendency of difference. SEM: Standard Error of Mean.

The study consisted of 4 treatment groups containing 0 g/kg, 0.1 g/kg, 0.2 g/kg, and 0.3 g/kg Triphala extract (TPHE1, TPHE2, TPHE3 and TPHE4).

Dietary TPHE decreased lipid oxidation in refrigerated quail breast meat, resulting in lower peroxide levels compared to the control (TPHE1) (P < 0.05). From day 3, TPHE4 decreased the most, followed by TPHE3 and TPHE2. Peroxide readings elevated in all groups during storage, although Triphala supplementation reduced oxidation from 3 days to 21 days.

## Discussion

### Growth performance

The current study provides data regarding the effects of varying concentrations of Triphala extract (TPHE) supplementation on quail growth performance, carcass characteristics, meat composition, peroxide value of breast meat. The results revealed that adding TPHE to the quail diets increased body weight gain and feed intake, and reduced the FCR during 0 to 6 weeks. It was reported that, dietary Triphala powder supplementation significantly improved growth performance and feed efficiency of fish (Jastaniah et al., 2024; Elabd et al., 2025) and broiler (Madhupriya et al., 2020). The supplementation of phytobiotics (Amla and Tulsi leaf powder) separately or in combination positively impacted the body weight gain, but not affected the feed intake or FCR in case of Japanese quail (Sumanth et al., 2024). It was stated that, amla and green tea aqueous extract or their combination has impact on feed intake and egg production compare to the control treatment in case of laying Japanese quail (*Coturnix coturnix japonica*) (Kamil et al., 2021).

Madhupriya et al. (2020) suggested that Triphala might be used at 0.10 percent in broiler diets as an alternative to antibiotic growth promoters to enhance the production performance of broiler chickens. According to another study, *E. officinalis* (Amla) at 5% and 10% concentrations with arsenic enhances feed consumption and body weight compared to the arsenic fed group (Ther et. al., 2017). Studies indicated that body weight and weight gain at the conclusion of the trial were greater in the amla-treated group compared to the control group at both ambient temperature and heat stress conditions. In broiler, Triphala supplementation generally may increase growth rate and feed conversion ratio. The performance of broiler may improve from Triphala's antioxidant, immunogenic, and hypolipidemic qualities (Baliga et al., 2012). The supplementation of amla fruit powder enhanced the feed conversion ratio (FCR) and dressing % compared to the control groups (Kazal et. al., 2023). To our knowledge, there are limited published studies examining the effects of dietary Triphala extract supplementation in growth of quail. But the dietary supplementation of Triphala extract may improve the growth performance of quail.

### Carcass characteristics

Carcass characteristics have been recognized as crucial response parameters for evaluating dietary energy and amino acid status in livestock, including yields of breast muscle, thigh muscle, and abdominal fat (Tang et al., 2021). Our findings suggested that highly significant variance in carcass yield was observed in TPHE4 than other treatment groups. Again, weight of hot and cold carcass was higher in TPHE3 & TPHE4 compared to remaining treatments. According to (Madhupriya et al. 2020), it was determined that carcass characteristics (eviscerated carcass, gizzard, heart and abdominal fat) exhibited no significant differences among the various treatment groups due to the supplementation of Triphala, with the exception of the percentage yield of the liver. In our study, we also found that there was no statistically significant difference in thigh, wings, back, neck percentages except breast percentage. Ma et al. (2015) found that supplementation with flavonoids from sea buckthorn fruits did not significantly affect dressing percentage, eviscerated yield, and breast and thigh meat percentage. Our findings also demonstrated that dietary supplementation with Triphala did not exhibit any significant effect on carcass characteristics.

### Meat composition

Quail meat is regarded as a high-quality protein source due to its favorable amino acid composition. Breast and leg meat comprise essential amino acids including cysteine, phenylalanine, isoleucine, leucine, lysine, methionine, tyrosine, threonine, and valine as well as non-essential amino acids such as alanine, arginine, asparagine, glycine, glutamine, histidine, proline, and serine (Genchev et al., 2008). Quail meat also contains several minerals, such as calcium, phosphorus, sodium, potassium, magnesium, iron, copper, and zinc (Genchev et al., 2008; Cullere et al., 2018). In adequate quantities, these minerals facilitate

the development of the skeletal system and promote the health of animals, as various minerals play a role in metabolic processes and the regulation of the body's acid-base balance (Ravindran, 2014). In relation to chemical composition, the Japanese quail carcass (at 35 to 42 days of age) is consisting of 68% water, 19% protein, 10% fat, and 3% minerals (Genchev et al., 2008).

The meat (breasts and legs) consists of 71% to 74% water, 17% to 23% protein, 2% to 8% fat, and 1.5% to 1.8% minerals (Hamm and Ang, 1982; Genchev et al., 2008; Morón-Fuenmayor et al., 2008). The protein content of both the carcass and meat aligns with the literature, indicating 19.0% for the carcass and 20% and 23% for the legs and breasts, respectively, of broiler chickens (Du and Ahn, 2002; Lee et al., 2012), yet it is lower than that of red meat, which ranges from 20% to 25% (Williams, P., 2007). The fat content of the leg and breast meat of Japanese quails is 3.3% and 2.5% respectively (Genchev et al., 2008). These values are within the range documented for beef (*Longissimus dorsi*) with light marbling (2.1% to 3.7%) but lower than those reported for lamb meat (Longissimus dorsi; 8%) (Hoke et al., 1999; Torrescano-Urrutia et al., 2017). In our study, a notable and dose-dependent increase in crude protein content, with the maximum protein concentration was observed in TPHE4. The enhancement in protein deposition may be attributed to improved nutritional digestibility and amino acid utilization resulting from Triphala supplementation, as it contains numerous phytochemicals, including tannins, phenolics, saponins, flavonoids, gallic acid, chebulagic acid, chebulinic acid, vitamin C, and others are abundant in Triphala (Baliga et al., 2012).

### Meat pH value

Meat pH is a critical quality parameter that usually reflects the post-mortem biochemical changes in muscle. The live muscle normally has a pH of approximately 7.0–7.2, which decreases post-mortem through anaerobic glycolysis of glycogen to lactic acid, reaching an ultimate pH (pHu) of about 5.4–5.8 within 24 hours (Lawrie & Ledward, 2006; Warner, 2017). This decline is essential for desirable meat characteristics such as color, tenderness, and water-holding capacity (WHC). If the post-mortem pH remains high (>6.0), meat tends to be dark, firm, and dry (DFD) due to insufficient lactic acid production, often caused by depleted glycogen reserves or metabolic stress prior to slaughter (Velasco & Williams, 2011). Conversely, excessively rapid pH decline at high carcass temperatures can result in pale, soft, exudative (PSE) meat, characterized by reduced WHC and inferior processing quality (Warner, 2017). Initial pH value did not differ among the dietary treatments; nevertheless, lower pH value was depicted in the TPHE2, TPHE3 and TPHE4 as compare to TPHE1, indicates metabolic shifts that may influence muscle glycogen availability and pre-slaughter energy status. Such changes can impact the rate and extent of post-mortem pH decline, thereby affecting ultimate meat quality, including color, tenderness, and shelf-life. Lower pH value in the TPHE supplemented group might be attributed to lower lipid oxidation and putrefaction due to bioactive compounds generated by TPHE extract.

### Peroxide value of meat

The peroxide value serves as a prominent indicator of primary lipid oxidation, reflecting the initial oxidative alterations in meat during storage. Understanding the impact of natural antioxidants on meat quality is crucial. The high storage temperature facilitated the product's oxidation (Macari et al., 2022). The oxidative process of meat influences colorimetric characteristics due to lipid oxidation, as lipid sources are abundant in fatty acids, rendering them more vulnerable to oxidation. The by-products of lipid oxidation can engage with proteins, amino acids, and peptides, promoting protein oxidation, which may lead to the depletion of essential amino acids and alterations in biological structure and function (Domínguez et al., 2021). In our study, on day 0, no significant differences were identified across treatments, demonstrating that TPHE supplementation did not alter the oxidation of fresh quail breast meat.

From day 3, TPHE-supplemented groups showed considerably reduced peroxide values compared to the control, with a dose-dependent decrease. Throughout storage, TPHE4 consistently exhibited the lowest peroxide values, indicating superior oxidative stability of the meat. The result can be ascribed to the antioxidant characteristics of Triphala, which include bioactive substances that can neutralize free radicals and impede lipid peroxidation. Ibraheem et al. (2022) also found that the peroxide values in treatments 2 (3.5 g/kg of onion), 3 (7 g/kg of onion), 4 (5 g/kg of sumac), and 5 (10 g/kg of sumac) were lower than the control group, due to the antioxidant properties of onion and sumac, which reduce peroxide levels. According to Naımatı et al. (2022) the peroxide value, the principal oxidation product, was observed to be lower in the diet containing quinoa seed extracts compared to the control group for quail which is similar to our studies. No previous study has directly reported peroxide value outcomes in quail breast meat following the administration of Triphala.

## Conclusions

The addition of TPHE to the quail diet enhanced feed intake and body weight gain. Carcass characteristics and meat composition was positively influenced by supplementation of TPHE. The peroxide values of meat, the primary oxidation product, were observed to be lower in the TPHE added groups than no TPHE with the increase of storage duration. According to the present research, the best results was exhibited for performance, carcass characteristics, meat composition and meat storage parameters while supplemented with 0.2 g/kg and 0.3 g/kg TPHE in case of quail. Thus, TPHE (0.2 g/kg and 0.3 g/kg) could be suggestive in poultry feed for better performance, carcass characteristics, meat composition and to delay lipid oxidation of meat.

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