

Original research article

Weight Gain, Morphometrics, and Reproductive Characteristics of Japanese Quails (*Coturnix coturnix japonica*) Fed with Powder of Elephant Apple (*Dillenia indica*) Fruit

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ABSTRACT

This study aims to evaluate the suitability of using graded levels of Elephant apple (*Dillenia indica*) fruit meal as a feed additive for weight gain, morphometric measurements, and reproductive characteristics in Japanese quail. The Elephant apple fruit was sliced thinly and dried in an air-circulation oven at 40 °C until the weight stabilized. The dried apple was ground into a fine powder and stored in airtight zip-lock bags for future use. Four treatment groups, each comprising 76 quails, were used in this study: control, T1 (0%), T2 (0.5%), T3 (0.75%), and T4 (1%), in a completely randomized design. Each treatment had 19 quails in three replications of 6, 6, and 7, and the experiment lasted 12 weeks. Some growth and reproductive parameters were measured. For weight gain, height, shank length, and shank, T3 gave the best results of 217.9 g, 12.9 cm, 2.8 cm, and 1.8 cm, respectively, and the lowest were from T1. For most reproductive parameters, T3 (0.75%) still gave the best in terms of fertility and hatchability, with total rates of 71.4% and 91.8%, respectively, as compared to T1, T2, and T4 groups. It could be concluded that the best inclusion level for dried Elephant apple fruit meal in quail diet is 0.75% because it gave almost the best values in most growth and reproductive parameters of quails. From the findings, it was observed that T3 (0.75%) yielded the best growth and reproductive parameters, although this difference was not statistically significant in most cases at $p \geq 0.05$.

Keywords: Elephant apple; quails; growth parameters; poultry; *Dillenia indica*; Cameroon.

RÉSUMÉ

Cette étude vise à évaluer l'intérêt de l'utilisation de différents niveaux d'incorporation de la pulpe de fruit de pomme d'éléphant (*Dillenia indica*) comme additif alimentaire pour améliorer le gain de poids, les paramètres morphométriques et les caractéristiques reproductives de la caille japonaise. Les fruits de pomme d'éléphant ont été finement tranchés, puis séchés dans une étuve à circulation d'air à 40 °C jusqu'à stabilisation de leur poids. Les fruits séchés ont ensuite été broyés en une poudre fine et conservés dans des sachets hermétiques à fermeture zip pour une utilisation ultérieure. Quatre groupes expérimentaux, comprenant chacun 76 cailles, ont été utilisés selon un dispositif complètement randomisé. Les traitements étaient les suivants : groupe témoin (T1 : 0 %), T2 (0,5 %), T3 (0,75 %) et T4 (1 %). Chaque traitement comprenait 19 cailles réparties en trois répétitions de 6, 6 et 7 sujets. L'expérience a été menée pendant une période de 12 semaines. Plusieurs paramètres de croissance et de reproduction ont été évalués. En ce qui concerne le gain de poids, la hauteur corporelle, la longueur du tarse et le diamètre du tarse, le traitement T3 (0,75 %) a donné les meilleurs résultats, avec respectivement 217,9 g, 12,9 cm, 2,8 cm et 1,8 cm. Les valeurs les plus faibles ont été enregistrées chez les sujets du groupe T1. Pour la majorité des paramètres reproductifs, le traitement T3 (0,75 %) a également obtenu les meilleurs résultats, notamment en ce qui concerne les taux de fertilité et d'éclosion, qui ont atteint respectivement 71,4 % et 91,8 %, comparativement aux groupes T1, T2 et T4. Il peut donc être conclu que le niveau d'incorporation optimal de la poudre de fruit séché de pomme d'éléphant dans l'alimentation des cailles serait de 0,75 %, puisqu'il a permis d'obtenir les valeurs les plus favorables pour la majorité des paramètres de croissance et de reproduction étudiés. Les résultats montrent ainsi que le traitement T3 (0,75 %) a produit les

meilleures performances de croissance et de reproduction. Toutefois, dans la plupart des cas, les différences observées n'étaient pas statistiquement significatives au seuil de $p \geq 0,05$.

Mots-clés: Pomme d'éléphant ; cailles ; paramètres de croissance ; aviculture ; *Dillenia indica* ; Cameroun.

1. INTRODUCTION

The poultry industry in Cameroon is not well developed, with a focus mainly on chicken meat, with very little diversification of poultry meat in our restaurants. Japanese quails (*Coturnix coturnix japonica*) have gained popularity due to their rapid growth rate, short production cycle, and adaptability to intensive housing systems. There is an increase in demand for quail products for consumption due to their medicinal properties in treating human ailments (Sati et al. 2012). Increased diversification into the production of livestock species such as quail with short generation intervals could be a viable option in ameliorating the shortage of protein among the populace in developing countries (Muthukumar & Dev Roy 2005). There is, however, a need to diversify poultry farming, offering consumers new taste options and increasing meat production to meet the ever-increasing demand for animal protein. Quail farming, or cuniculture, has been attracting the attention of experts for some time due to the many benefits attributed to quail products, some of which are: they have been widely used in scientific research because of their small size, rapid generation turnover, and disease resilience, making them suitable models for poultry research. Quail meat and eggs are also rich in nutrients and tasty for consumers (Mamizade et al. 2013, Marie-Claire et al. 2022).

Modern poultry farming faces challenges such as improving feed efficiency, growth performance, and reproductive traits while ensuring sustainability and minimizing environmental impacts (Lima et al. 2022). Quail production is still relatively niche/small-scale compared with the broiler and layer chicken industries in Cameroon. Production and marketing are often driven by small private farms and urban/peri-urban producers, with products mainly sold through local networks and restaurants rather than mass channels (cameroon-tribune.cm). However, quails are increasingly considered a “new” or alternative poultry activity because they can be raised in small spaces and are used for both meat and eggs (Katchouang et al. 2015).

Japanese quail (*Coturnix coturnix japonica*) is a fast-growing bird that has a short generation interval compared to some domestic poultry birds. At five weeks, broiler quails can be sold, and layer quails start laying at the age of 6 weeks and continue laying eggs for up to 24 weeks (Khalidari et al. 2010). Quails require smaller housing systems and less labour-intensive systems as compared to chickens and other domestic livestock. Japanese quail is a promising genetic resource with higher returns, and this makes it suitable for production. The success of quail meat production has been strongly related to improvements in growth, egg quality, and carcass quality. In recent years, research into natural feed additives has gained momentum as an alternative to synthetic growth promoters, which are often associated with potential health hazards and regulatory restrictions. Some of those natural feed additives acting as growth promoters in the poultry industry in Cameroon include *Moringa oleifera*, *Aloe vera*, *Vernonia spp.*, *Carica papaya*, etc. One of the most important natural feed additives is *Dillenia indica*, commonly known as Elephant apple. With the recent law on the production of organic and safe food in Cameroon, this work is part of the policy under implementation in Cameroon's Agenda 2030 regarding the animal feed industry and safe food production. The use of these Elephant apple fruits in poultry production will help eliminate waste and boost the organic poultry production sector in Cameroon, thereby alleviating poverty and improving the quality of life, especially in rural parts of Cameroon, where these fruits are usually present and not used by the population.

According to Sarma et al. (2017), *Dillenia indica* is commonly known as Elephant apple and is a deciduous tree native to tropical and subtropical regions of Southeast Asia, particularly in India, Bangladesh, Sri Lanka, and parts of Southeast Asia. Among the various forms of agroforestry waste, the Elephant apple, which is an underutilized fruit, holds potential as an unconventional feed source for poultry and other farm animals. The Elephant apple is a fruit that grows abundantly in certain regions of Southeast Asia. However, it is often overlooked and goes to waste if not utilized promptly (Deshmukh et al. 2019). Elephant apple fruit is known to contain various nutritional components such as carbohydrates, proteins, vitamins, and minerals, which are essential for the growth and development of poultry (Saikia et al. 2023). By processing and incorporating Elephant apple into poultry rations, we can tap into this resource and contribute to the sustainable production of poultry feed. The inclusion of Elephant apple in poultry diets offers several advantages: it helps bridge the feed gap by providing an alternative and potentially abundant source of nutrients; utilizing Elephant apple as a feed resource contributes to sustainable agriculture practices; by incorporating agroforestry waste like Elephant

apple, we can reduce the dependence on traditional feed sources, which are often associated with environmental concerns and limited availability. This promotes the efficient use of resources and minimizes the ecological footprint of the poultry industry (Saikia et al. 2023).

There is an increasing global demand for poultry products that has driven the intensification of poultry farming, necessitating the exploration of sustainable and cost-effective strategies to enhance production efficiency (FAO 2023). There is an increasing use of natural feed additives in poultry production because meat from such products is safe for human consumption. According to research conducted by DAS et al. (2020) and Saikia et al. (2023), Elephant apple is rich in bioactive compounds such as ascorbic acid, phenolics, vitamins, proteins, carbohydrates, flavonoids, and tannins, exhibiting antimicrobial, antioxidant, and anti-inflammatory properties. These Elephant apples found in Buea, Cameroon, are being underutilized and causing environmental pollution. Their inclusion helps bridge the feed gap by providing an alternative and potentially abundant source of nutrients, thereby promoting the efficient use of resources and minimizing the ecological footprint of the poultry industry in Cameroon. This study aims to evaluate the suitability of using graded levels of Elephant apple (*Dillenia indica*) fruit meal as a feed additive for weight gain, morphometric measurements, and reproductive characteristics in Japanese quail.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted in the poultry unit of the Farmhouse, Faculty of Agriculture and Veterinary Medicine at the University of Buea, a city at the foot of Mount Cameroon in the Southwest Region of Cameroon (Figure 1). Buea is the capital of the Southwest Region of Cameroon, located at approximately 4°10'N latitude and 9°14'E longitude. Situated on the eastern slopes of Mount Cameroon, it falls under the West Africa Standard Time zone (UTC+1). This region provides a favorable climate conducive to quail production and the growth of Elephant apple. It experiences diverse temperature and humidity levels due to its varied topography, with cooler, cloudier conditions at higher elevations of approximately 4,095 m above sea level. Buea has a tropical climate with two distinct seasons: the rainy season, which lasts from March to November, and the dry season, which spans from November to February, with annual rainfall ranging from 2000 mm to 5000 mm (Nkwatoh et al. 2010). The average temperature at the University of Buea ranges from 23°C to 25°C; a mild range well suited for quails and development.



Fig. 1: Map of the University of Buea (Source: OpenStreetMap contributors)

2.2. Research design

A total of 76 quails in a completely randomized design (CRD) were used and were equally distributed among the treatment groups. A total of four (4) treatments (T1, T2, T3, T4) with three replicates each were used for the experiment. T1 was the control with no addition of the Elephant apple, while T2(0.5% inclusion, T3(0.75%), and T4 had 1% inclusion of the Elephant apple in their diet. Quails used for the experiment were obtained at day-old to assess the impact of *D. indica* on the growth and reproductive characteristics of the quails. The animals were brooded and housed in standard cages at 25 °C on a 16 h light-dark cycle for reproduction. They were supplied with feed and water to meet their optimum growth and reproductive potentials. The experimental quails were housed in pens of surface area 0.75 m², and the experimental period with Elephant apple administration was four 12-week periods (5 weeks before the start of laying and 7 weeks during laying). Additionally, the chicks, after incubation, were followed up for 3 weeks to assess the post-*D. Indica* effects on survivability. Each treatment consisted of, 6,6,7 replicates of quails (2 males per replicate), and each treatment consisted of 19 quails. Figure 2 shows the experimental design.

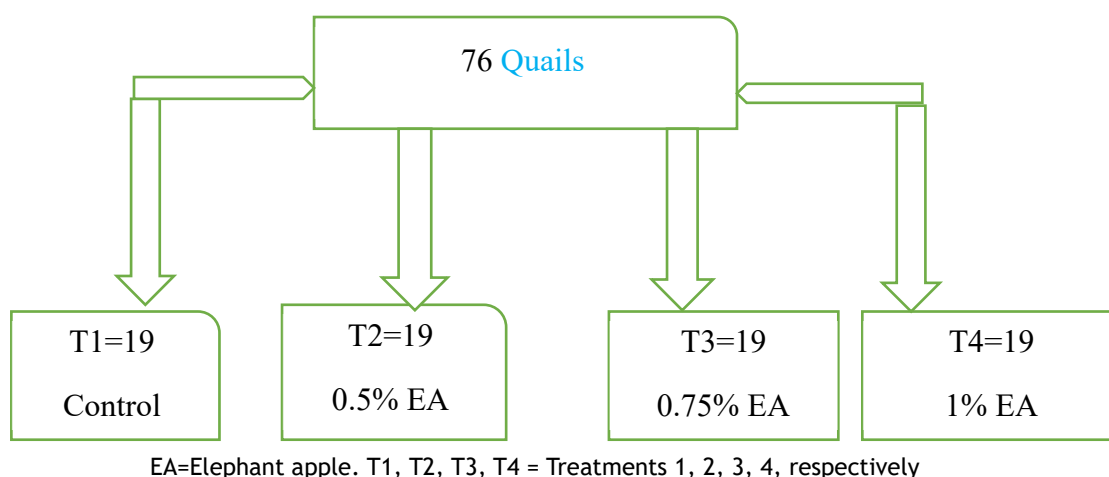


Fig. 2: Experimental design

2.3. Field layout of the experimental design

The pens in the research units were further partitioned using wood, plywood, and plastic nets. The partitioning was done to give rise to a total of 12 sub-pens of dimensions 1 m by 0.75 m with uniform dimensions. All pens had the same orientation to make sure that natural lighting, ventilation, and other environmental factors were uniform across treatments and replicates. Provision for nighttime lighting was also made available by placing a total of eight 4, 15W bulbs producing white light through an automatic system. See Figure 3 for the experimental layout.

T3R2	T2R1
T1R2	T0R2
T0R1	T1R1
T3R3	T2R2
T0R3	T3R1
T2R3	T1R3

T1, T2, T3, T4 = Treatments 1, 2, 3, 4, respectively.

R1, R2, R3 = Replicates 1, 2, 3, respectively

Fig. 3: Field and experimental layout of the research design

2.4. Ethical and administrative issues related to experimental animals

The experiments were carried out following the National Ethical Committee Guidelines (N°FWA-IRB00001954) and international guidelines (European Committee Council Directive of November 24, 1986 (86/69/EEC); Guide for the Care and Use of Laboratory Animals, U.S. National Research Council 1996) for the care and use of laboratory animals. All efforts were made to minimize the suffering and stress of any type to the chickens used.

2.5. Processing of *Dillenia indica* fruit before inclusion into the feed as an additive

The fruits were harvested and washed with clean water to remove dirt. These fruits were then chopped with the aid of a knife to reduce the size of the fruits, thereby increasing the surface area for drying. Subsequently, the weight of the fresh *D. indica* was recorded. The chopped fruits were spread in an air-circulating oven dryer at 40 °C to dry. The *D. indica* fruit was weighed at intervals until the weight became fairly constant after 72 h. The dried apple fruits were then bagged and carried to the mill, where they were ground into powder, ready to be added. It was ground into powder using a pulverizer machine at the Faculty of Agriculture and Veterinary Medicine Training and Research Farm (FAVM-TRF) feed mill and stored in airtight plastic bags to avoid moisture that could lead to fungal growth. All experimental ingredients (excluding maize), such as wheat bran, soybean meal, fish meal, premix, and bone meal, were purchased from BELGOCAM (a Standard feed Company in Cameroon), Buea branch. The maize (yellow maize) used for the research was purchased from Bangem in the Southwest Region of Cameroon. Figure 4 shows *D. indica* root meal powder obtained from fruit processing.

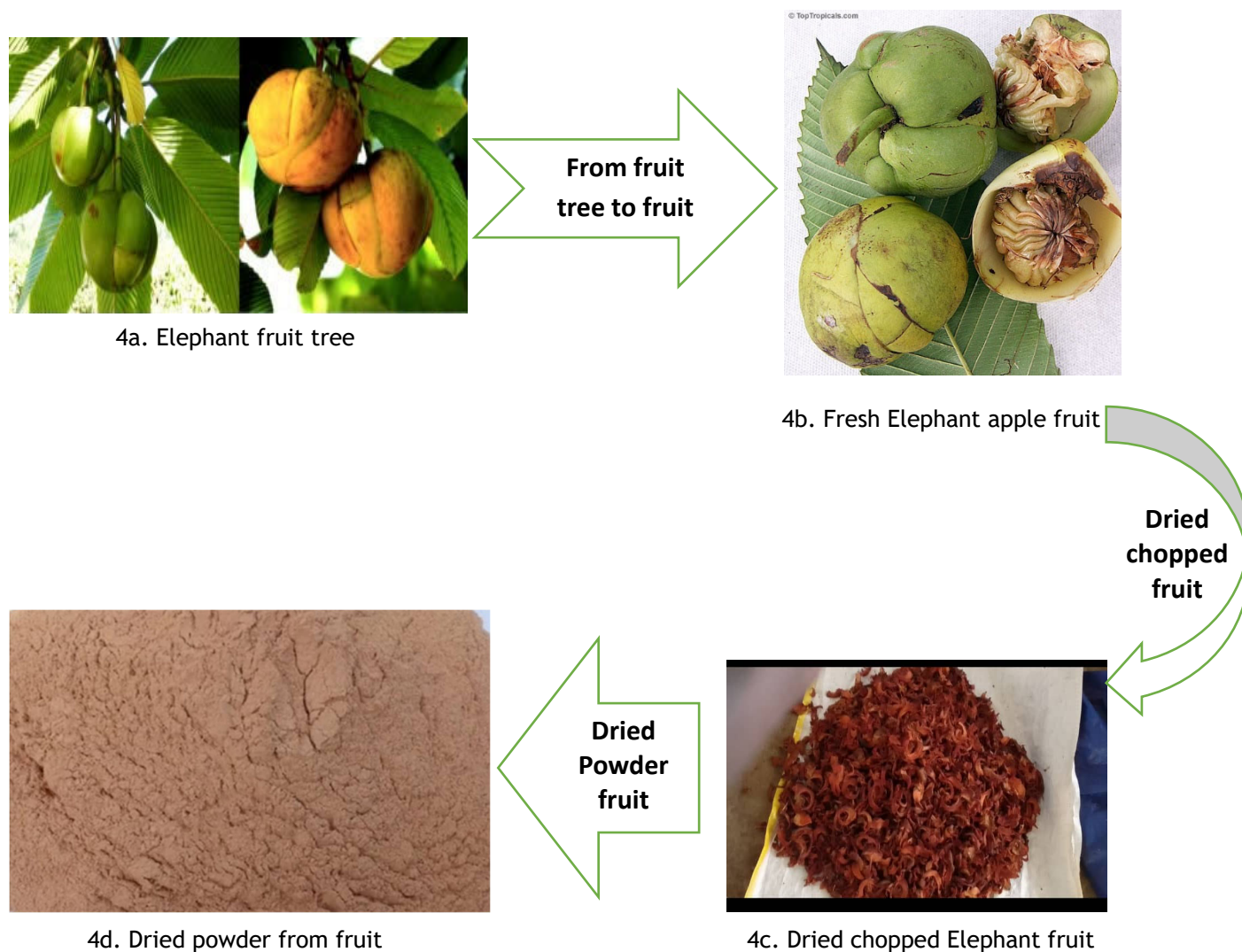


Fig. 4: Processing of *Dillenia indica* fruit before inclusion into the feed

2.6. Quails' diet formulation

The basal diet for the experiment was formulated in accordance with the National Research Council nutrient requirements for poultry (NRC 1994). The basal diet was prepared, ensuring the mash was isocaloric and isonitrogenous. The calculated chemical composition of the feed was made to be within the range recommended by the NRC for breeders (quails). Four test diets were prepared, and for each treatment, the ingredients were weighed separately, starting with the macro ingredients using an electronic scale with a maximum capacity of 2 kg ± 1 g. The micro-ingredients were weighed using the SF-400 electronic kitchen scale. The micro-ingredients were first mixed and introduced to the macro ingredients, and mixed thoroughly using a mixer. The resulting

mash was weighed, bagged, and tagged as treatment zero (T1), which served as the control. This procedure was repeated for all the other treatments, except *D. indica* fruit, which served as the additive (test ingredient), and was mixed alongside the micro-ingredients at varying proportions of 0.5%, 0.75%, and 1%. The resulting mash was then weighed, bagged, and tagged T1, T2, and T3, respectively (Nghonjuyi et al. 2024). The diets contained 24.802% crude protein, 2.97% crude fiber, 1.09% Ca, 1.56% lysine, and 0.489% methionine, with a corresponding metabolizable energy of 2816.48 kcal/kg (Table 1).

Table 1: Experimental formulation of Japanese quail

Feed Ingredients	Quantity for Starter (Kg)	Quantity for Grower (Kg)	Quantity for Finisher (Kg)
Maize	52	45	45
Wheat bran	7	5	5
Soybean	30	35	35
Fishmeal	7	10	10
Bone meal	2	2	2
Premix	2	2	2
Total	100	100	100
Nutritional Values			
Crude Proteins(%)	24.802		
Met. Energy (kcal/kg)	2816.48		
Crude Fiber(%)	2.97		
Calcium(%)	1.09		
Phosphorus(%)	0.787		
Sodium(%)	0.026		
Lysine(%)	1.56		
Methionine(%)	0.489		

2.7. Management of quails during the experiment

The birds were kept in an open-sided building made of cement blocks and roofed with an iron sheet. In preparation for the arrival of day-old chicks, a brooder was constructed with planks, wire nets, and sealing papers to prevent heat loss. The floor of the brooder was made of concrete, and cartons were placed on the concrete and wood shavings as bedding material. During this stage, 60-watt bulbs were used as lighting and heating systems during the day and at night. When the birds were three weeks of age, they were transferred to the experimental pens. A total of 12 experimental cages were constructed for the quails, and each cage was labeled based on the treatments and replicates. These experimental cages were made of plank floors; fine wire mesh was used at the sides, partially to create a firm separation between pens, and coarse wire nets were used to complete the sides; they were covered using plastic nets. Daily temperature and humidity were recorded at the experimental site. Temperature ranged from 23.3-24 °C and humidity ranged from 89-99% since the experiment was done in the rainy season. Feed and water were given *ad libitum*.

The eggs collected were tagged according to treatment and the replicates from which they came. These eggs were stored in an insulated box with controlled temperatures (16 and 18 °C) and humidity (75-85%) suitable for preservation. The eggs were cleaned and disinfected with wet 70 % alcohol using a wet foam. Before incubation, the incubator was cleaned using bleach (NaClO). The incubation temperature and humidity were set at 37.5 °C and 65 % humidity, respectively. The incubation of the quail eggs took 21-22 days, similar to chicken eggs. On the 19th day of incubation, the eggs were transferred to the hatcher with the temperature and humidity regulated to 36.5 °C and 68 %, respectively. They were transferred according to the treatment. All eggs were withdrawn from the incubator, and embryo mortality was evaluated on day 23.

2.8. Data collection and studied characteristics

Data collected during the experiments included weekly weight gain and some morphometric parameters like height, feather length, shank height, shank length, and shank circumference. In addition, we collected data on some reproductive parameters like the weekly number of eggs laid, the weekly weight of eggs, fertility rate, hatchability rate, embryo mortality rate, survivability rate after a week, and hatchability weight.

Weekly body weights were recorded by measuring all the quails in each replicate using an electronic balance with 0.01 g sensitivity. The weight for each treatment was recorded as the mean of the three replicate samples for each treatment. For morphometric measurements, the shank circumference was measured using a vernier calliper to the nearest centimeter. The shank length, feather length, and quail height were measured with the ruler of the vernier callipers. All these parameters were taken weekly in all the treatments, and the results were recorded.

Weekly egg laid was a function of the weekly number of eggs collected per replicate per treatment. The weight of the chicks immediately after hatching (HWt) was measured with the use of a sensitive electronic balance.

To measure fertility, hatchability rate, and hatching weight, quail eggs were incubated, and the total number of eggs incubated per treatment was recorded. On the 19th day of the incubation period, the eggs were transferred to hatching baskets labelled according to their treatments and taken to the hatcher. Each basket was partially modified to ensure that chicks do not fall from one treatment to another upon hatching. All hatched chicks were counted and recorded according to the treatment from which they originated. On day 21 of incubation, all unhatched eggs were withdrawn from the incubator, cracked open, and embryo mortality was evaluated and recorded. When the chicks were brought to the farm from the incubator, their hatching weights (HW) were recorded using the sensitive electronic balance. The total number of fertile eggs was the sum of the total number of hatched chicks and the total embryo mortality per treatment. It was calculated using the formula:

$$\text{Fertility Rate (FR)} = \frac{\text{Number of fertile eggs}}{\text{Number of eggs incubated}} \times 100$$

$$\text{Hatchability Rate} = \frac{\text{Number of hatched chicks}}{\text{Number of fertile eggs}} \times 100$$

Embryo mortality was determined after incubating the eggs (day 21). The unhatched eggs were cracked and examined for the presence of embryos that had developed and died during incubation. The number of embryo deaths was counted and recorded. The total number of quail chicks that survived from each treatment after 21 days was evaluated and recorded. A well-constructed, partitioned, and labelled brooder was used for this trial. Each chick was placed in the brooder compartment corresponding to the treatment from which it was hatched. The chicks were fed, and water was provided *ad libitum* daily for 3 weeks.

2.9. Data analysis

All data collected for each parameter were subjected to statistical analysis using GraphPad Prism version 9.0 statistical software. Descriptive statistics were calculated for each parameter to obtain the corresponding means and standard deviations. Furthermore, one-way ANOVA and Tukey's multiple comparisons test were used to identify significant differences among means. Significance was set at $p \leq 0.05$.

3. RESULTS

3.1. Effects of the dried Elephant apple fruit powder on the weight gain of quails

The weight gain by quails with supplemented graded levels of *D. indica fruit* feed is shown in Figure 5, and the statistical significance was established at $P \leq 0.05$. The highest weight gain at week 9 was observed in T3 (0.75%), while the least was in T2, although there was no significant ($p \leq 0.05$) difference

3.2. Effect of the dried powder of Elephant apple fruit on the height of quails

The increase in quail heights supplemented with graded levels of *D. indica fruit* is shown in Figure 6. In the 9th week, T3 showed significantly ($p \leq 0.05$) the highest height (12.9 cm) as compared to other groups, while the least increase was seen in T2 (11.7 cm).

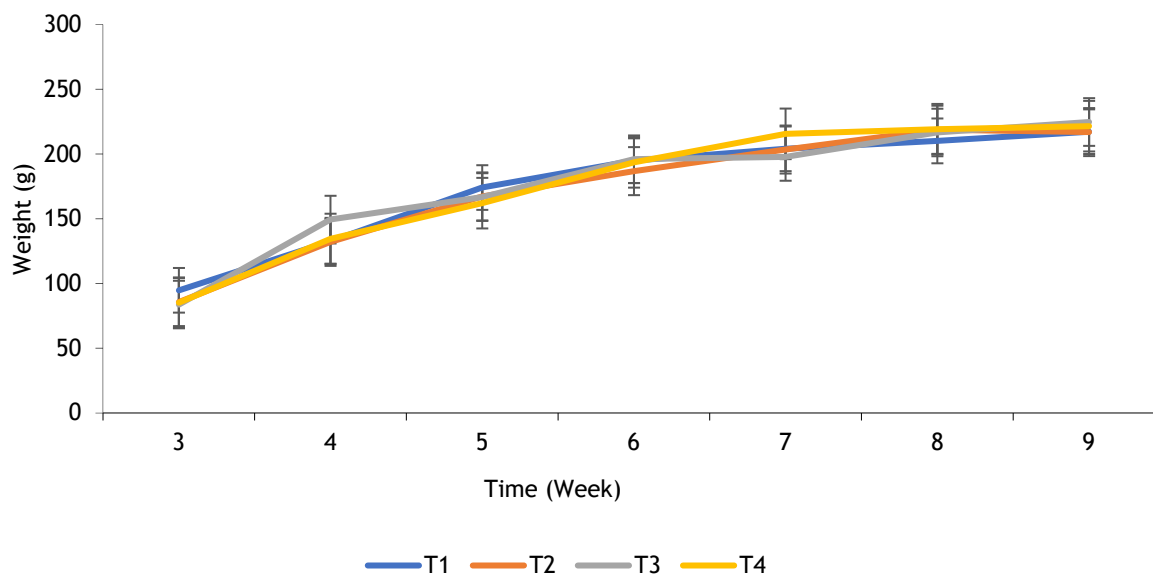


Fig. 5: Weekly weight gain of quails fed different levels of Elephant apple fruit meal. T1=control with no addition; T2=0.5% inclusion; T3=0.75% inclusion; and T4=1% inclusion of Elephant apple dried fruit in the quail diet.

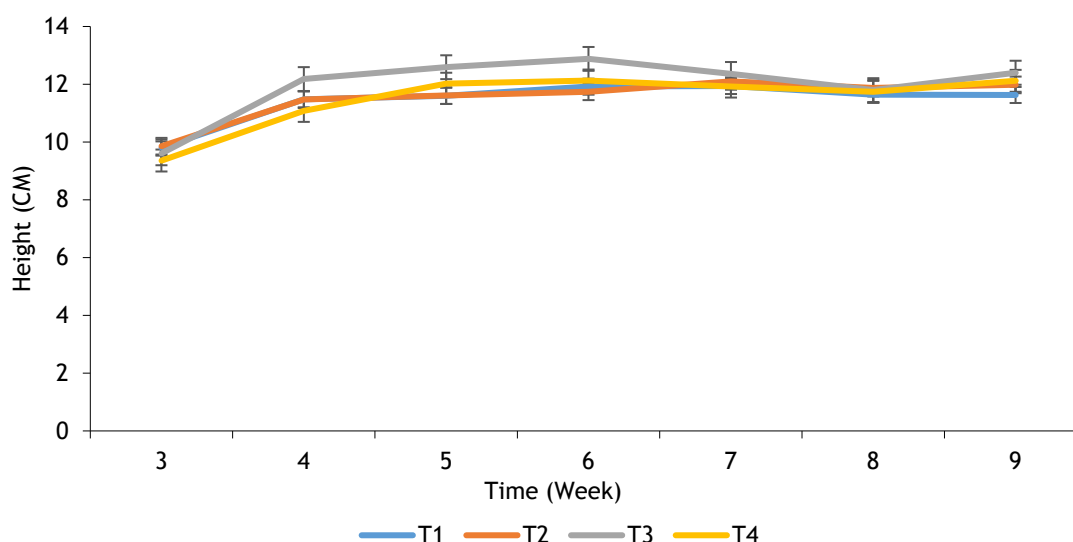


Fig. 6: Weekly change in height of quails fed different levels of Elephant apple fruit meal. T1=control with no addition; T2=0.5% inclusion; T3=0.75% inclusion; and T4=1% inclusion of Elephant apple dried fruit in the quail diet.

3.3. Effect of the Elephant apple fruit powder on the shank length of Japanese quails

The increase in quail shank length supplemented with graded levels of *D. indica fruit* is shown in Table 2. The highest length increase at week 9 was observed in T3 (2.84), while the least increase was seen in T2 (2.76), and there was no significant ($P > 0.05$) difference within the treatment groups. There seems to be a positive correlation between weight gain, height, and shank length and shank circumference in quails fed with Elephant apple at the dose of 0.75% inclusion.

3.4. Effect of the Elephant apple fruit powder on the shank circumference

The increase in quail shank circumference with supplemented feed of graded levels of *D. indica fruit* is shown in Table 3. The highest circumference increase at week 9 was observed in T3 (1.76), while the least increase was seen in T2 (1.73). However, there was no significant ($P > 0.05$) difference among treatment groups.

Table 2: Shank length of quails fed Elephant apple fruit powder

Week	Shank Length $\pm$ SEM (cm)			
	T1	T2	T3	T4
3	2.35 $\pm$ 0.05	2.31 $\pm$ 0.05	2.28 $\pm$ 0.05	2.23 $\pm$ 0.05
4	2.39 $\pm$ 0.05	2.46 $\pm$ 0.05	2.40 $\pm$ 0.05	2.38 $\pm$ 0.05
5	2.40 $\pm$ 0.04	2.46 $\pm$ 0.04	2.44 $\pm$ 0.04	2.45 $\pm$ 0.04
6	2.45 $\pm$ 0.04	2.48 $\pm$ 0.04	2.53 $\pm$ 0.04	2.51 $\pm$ 0.04
7	2.56 $\pm$ 0.04	2.50 $\pm$ 0.04	2.60 $\pm$ 0.04	2.61 $\pm$ 0.04
8	2.64 $\pm$ 0.04	2.53 $\pm$ 0.04	2.71 $\pm$ 0.04	2.71 $\pm$ 0.04
9	2.78 $\pm$ 0.04	2.76 $\pm$ 0.04	2.84 $\pm$ 0.04	2.81 $\pm$ 0.04

SEM = Standard error of the mean. T1=control with no addition; T2=0.5% inclusion; T3=0.75% inclusion; and T4=1% inclusion of Elephant apple dried fruit in the quail diet.

Table 3: Shank circumference of quails fed Elephant apple fruit powder

Week	Shank Circumference $\pm$ SEM (cm)			
	T1	T2	T3	T4
3	1.23 $\pm$ 0.03	1.18 $\pm$ 0.03	1.16 $\pm$ 0.03	1.23 $\pm$ 0.03
4	1.31 $\pm$ 0.03	1.60 $\pm$ 0.03	1.60 $\pm$ 0.03	1.52 $\pm$ 0.03
5	1.64 $\pm$ 0.03	1.62 $\pm$ 0.03	1.63 $\pm$ 0.03	1.60 $\pm$ 0.03
6	1.67 $\pm$ 0.03	1.64 $\pm$ 0.03	1.66 $\pm$ 0.03	1.68 $\pm$ 0.03
7	1.69 $\pm$ 0.03	1.67 $\pm$ 0.03	1.70 $\pm$ 0.03	1.70 $\pm$ 0.03
8	1.71 $\pm$ 0.03	1.68 $\pm$ 0.03	1.71 $\pm$ 0.03	1.73 $\pm$ 0.03
9	1.76 $\pm$ 0.03	1.73 $\pm$ 0.03	1.76 $\pm$ 0.03	1.75 $\pm$ 0.03

SEM = Standard error of the mean. T1=control with no addition; T2=0.5% inclusion; T3=0.75% inclusion; and T4=1% inclusion of Elephant apple dried fruit in the quail diet.

3.5. Effect of the Elephant apple fruit powder on the feather length of Japanese quails

The increase in quail feather length supplemented with graded levels of *D. indica* fruit is shown in Table 4, and the highest feather increase at week 9 was observed in T4 (11.73), while the least increase was 11.25. However, there was no significant difference ($P > 0.05$) among treatment groups.

Table 4: Feather length of quails fed Elephant apple fruit powder

Week	Feather Length $\pm$ SEM (cm)			
	T1	T2	T3	T4
3	9.04 $\pm$ 0.15	9.08 $\pm$ 0.15	8.56 $\pm$ 0.15	8.44 $\pm$ 0.15
4	9.95 $\pm$ 0.15	10.32 $\pm$ 0.15	10.33 $\pm$ 0.15	10.03 $\pm$ 0.15
5	10.55 $\pm$ 0.12	11.01 $\pm$ 0.12	10.84 $\pm$ 0.12	10.68 $\pm$ 0.12
6	10.96 $\pm$ 0.12	11.04 $\pm$ 0.12	11.12 $\pm$ 0.12	11.04 $\pm$ 0.12
7	11.21 $\pm$ 0.12	11.24 $\pm$ 0.12	11.44 $\pm$ 0.12	11.34 $\pm$ 0.12
8	11.26 $\pm$ 0.12	11.40 $\pm$ 0.12	11.37 $\pm$ 0.12	11.52 $\pm$ 0.12
9	11.61 $\pm$ 0.12	11.62 $\pm$ 0.12	11.70 $\pm$ 0.12	11.73 $\pm$ 0.12

SEM = Standard error of the mean. T1=control with no addition; T2=0.5% inclusion; T3=0.75% inclusion; and T4=1% inclusion of Elephant apple dried fruit in the quail diet.

3.6. Reproductive Parameters of Quails under Deep Litter Fed Dried Powder Elephant Apple Fruit

Some reproductive parameters of quails fed Elephant apple fruit powder were measured. Some of these parameters were weekly egg production, eggs laid, fertility rate, Embryo mortality, hatchability rate, chick weights, survivability rate, and chick mortality.

The weekly egg production of quails was recorded, and the results are represented in Figure 7. Egg laying started in week 6, and the highest number of eggs was recorded in week 10, with a total of 230 eggs laid that week. The total number of eggs laid for the 6 weeks from the beginning of laying was 889 eggs. Details of weekly egg production are in Figure 7.

The weekly egg collection per treatment was done as shown in Figure 8. It was observed that T1 (control) showed the highest number of eggs after six (6) weeks, with a total of 329 eggs, while the least was T2 (0.5%), with a total of 144 eggs in 6 weeks, with a significant difference at $p \leq 0.05$. Details are in Figure 8.

Table 5 summarizes the effects of graded levels of *D. indica* fruit powder on egg quality, fertility, and survival of quails. With T1 yielding the highest number of eggs and T2 the least, it was observed that T3 (0.75) had the highest fertility rate of 91.8%, while T3 (1%) had the lowest fertility rate of 64.3%, and the differences were statistically significant at $p \leq 0.05$. The best hatching rate was from T3, with $p \leq 0.05$, at 71.4%, while the lowest was from T2, at 57.5%. The differences were significant among the treatments. Furthermore, there was a significant ($p \leq 0.05$) difference in embryo mortality between the treatment groups, with the highest embryo mortality of 23.3% recorded in T2 and the lowest in T1, at 7.3%. There was no significant difference in mortality rate after three weeks from the F1 generation, although the highest death rate was from T1 (7.9%), and the lowest was from T4 (3.7%).

Table 5: Effects of Elephant Apple Fruits Powder Meal on Egg Quality and Hatchability

Parameters	Treatment			
	T1	T2	T3	T4
Number of Eggs Incubated	54	40	49	42
Hatching Rate (%)	38 (70.4)	23 (57.5)	35 (71.4)	27 (64.3)
EMo Rate (%)	3 (7.3)	7 (23.3)	10 (22.2)	5 (15.6)
Fertility Rate (%)	41 (75.9)	30 (75)	45 (91.8)	32 (64.3)
Hatching Wt (g)	7.1±0.01	7.2±0.05	7.1±0.04	7.10±0.03
Survivability Rate (%)	3 (7.9)	1 (4.3)	2 (5.7)	1 (3.7)

T1=control with no addition; T2=0.5% inclusion; T3=0.75% inclusion; and T4=1% inclusion of Elephant apple dried fruit in the quail diet.

4. DISCUSSION

Low coefficients of variation ($CV < 25\%$) for morphometric traits indicate little within-group variation. This suggests that each group was phenotypically homogeneous, reflecting the low variation in the morphometric traits analyzed. This morphological homogeneity may be the result of slight variations in environmental conditions. This result can be explained by several mechanisms. Harti & Clark (2007) stated that in a stable, homogeneous environment, natural selection favors individuals with intermediate morphological traits (extremely short or long wings, shanks, height), whereas individuals with extreme traits are less likely to survive. This mechanism would reduce variation in morphological traits within a group. Moreover, Hanski & Gaggiotti (2004) stated that when essential environmental resources are evenly distributed, there is no need for individuals to develop specific morphological adaptations to exploit different ecological niches because there is no strong environmental evolutionary pressure.

The use of dry Elephant apple fruit as a feed additive for quails was motivated by its richness in triterpenoids (botulin and betulinic acid), flavonoids such as myricetin, quercetin, and kaempferol, ketones, phenols, and tannins. These ingredients have antioxidant, anti-inflammatory, antimicrobial, and health-promoting properties.

The present study evaluated the effects of incorporating Elephant apple (*Dillenia indica*) fruit meal as a feed additive on the growth and reproductive performance of Japanese quails (*Coturnix coturnix japonica*) under intensive housing conditions. The results demonstrated that quails fed with 0.75% Elephant apple fruit meal showed the best growth and reproductive performance. This could be because triterpenoids and flavonoids present in the experimental diets have some health-promoting properties, which might have kept the experimental quails healthy and thereby favored the growth and reproductive performance (Das et al. 2020).

For the growth and morphometric parameters (weight gain, shank height, shank circumference, quail height, and feather length), there was a greater increase in the experimental diet group than in the control, and this could be attributed to the health benefits of triterpenoids, flavonoids, and vitamins in Elephant apple. This finding suggests that *Dillenia indica* enhances nutrient digestibility and utilization, likely due to its flavonoids and tannins, which stimulate digestive enzyme activity, as reported by Khan et al. (2012) and Ranjan et al. (2018). Das et al. (2020) also reported that dietary inclusion of Elephant apple pulp improved growth rates in broiler chickens, likely due to its ability to enhance nutrient absorption and metabolic efficiency. Correlating

the growth and morphometric parameters employed in this study, one could say that there is a positive correlation between growth or weight gain and shank height, shank circumference, quail height, and feather length. This is similar to the work of Soro *et al.* (2025) on morphometric characterization of four strains of Japanese quail (*Coturnix coturnix japonica*) in the Ivory Coast.

For the Reproductive parameters of the quails, the following were investigated: number of eggs incubated, hatching rate, fertility rate, embryo mortality rate, and mortality rate for F1 after three weeks per treatment. T3 (0.75%) gave the best performance in hatching rate (71.4%) and fertility rate of 91.8% as compared to both the control and other experimental groups. This could be because the best dose for reproduction is 0.75% Elephant apple fruit powder. After all, it contains an adequate quantity of the active ingredients/minerals like vitamin C, antioxidants, oxidative stress properties, and health-promoting properties, which might have favored egg production and fertility. Chakraborty *et al.* (2019) found that while Elephant apple inclusion improved feed conversion ratio and growth in Japanese quails, it did not significantly enhance egg production, corroborating the findings of this study at a higher dose of the Elephant apple. Additionally, in a study on pigs by Singh *et al.* (2016), Elephant apple supplementation was associated with improved growth performance but no significant effect on reproductive indices. Comparing these findings to studies in other animal models reveals the importance of species-specific responses. Research on the effects of tannins, a key component of Elephant apple, has demonstrated variable outcomes across species and sources (Min *et al.* 2005).

5. LIMITATION OF THE STUDY

The work was on Japanese quails, and it was limited to the impact of Elephant apple on Japanese quails. The composition of Elephant apple from the literature was the reason that motivated us, and we didn't go further to analyze the Elephant apple for nutrient composition.

6. CONCLUSION

To conclude, Elephant apple fruit meal at 0.75% fed as an additive in diets of quails led to an improvement in some growth parameters like weight gain, shank height, circumference, and quails' heights. For reproductive parameters, most reproductive parameters, like egg laying, fertility rates, hatchability rates, and weights of chicks at day-old, were most improved at the 0.75% inclusion level of dried Elephant apple fruit powder given as a feed additive to the quails.

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