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Egg Production and Quality of Japanese Quails (*Coturnix japonica*) Fed Diets with various Levels of Pawpaw Pomace Meal (*Carica papaya L.*)

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ABSTRACT

The high cost of soybeans in developing countries is driving up feed expenses in poultry diets. This study sought to address this by replacing soybean meal with pawpaw pomace meal (PPM) in Japanese quail diets. 140 female quails were split into 4 groups in a completely randomized design and were reared for 56 days on varying levels of PPM in their diets consisting 0% 2.5%, 5% and 7.5% (designated as control, PPM2.5, PPM5 and PPM7.5 respectively). The quails were supplied respective feeds, and ordinary water *ad libitum*. The performance results showed hen-day-egg production (HDEP), feed intake (FI), egg weight (EW) and feed conversion ratio (FCR) were significantly (p<0.05) affected by treatment. PPM2.5 and PPM5 had the highest HDEP and the best FCR, while PPM 7.5 had the lowest HDEP and poor FCR. PPM7.5 had higher FI, while the control diet, PPM2.5 and PPM5 had lower FI. PPM5 had the highest EW, followed by PPM7.5, while the control diet and PPM had the lowest EW. In regard the egg quality performance, yolk colour, yolk weight, albumen weight and Haugh unit were significantly (p<0.05) affected by treatment. All the diets containing PPM had dark-yellowed yolk than the control diet. PPM2.5 and PPM5 had higher yolk and albumen weights, while PPM7.5 had lower. In a different trend, the control diet, PPM2.5 and PPM5 had higher Haugh unit, while PPM7.5 had lower Haugh unit. The optimal choice for egg production and quality was concluded to be the 5% inclusion level of PPM in the quail diets.

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INTRODUCTION

Currently, Nigerians like in most developing countries are facing tough economic times, with the prices of animal proteins being out of reach for many people who earn less than $1 per day (Edache et al., 2005). Among these proteins, eggs are more affordable. Quails are easier to handle compared to other poultry species due to their size and feed consumption (Oluyemi and Robert, 1979). These birds start laying eggs earlier than other egg-producing birds (Basri and Sulastri, 2021; McNaughton, 2018; Oluyemi and Roberts, 1979). Developing low-cost feed for quails can make quail production much less expenses, making it feasible for low-income individuals to raise them (Tamiru et al., 2021). Pawpaw (*Carica papaya* L.) belonging to the family of *caricacea*e (Rhmani and Aldebasi, 2015). Pawpaw, a fruit rich in essential nutrients, is widely grown in Nigeria and its by-products are increasingly being utilized in various projects (Adebayo-Oyetoro et al., 2016). Pawpaw fruit contains high levels of micronutrients such as vitamin C and β-carotene, which is a precursor of vitamin A. (Adebayo-Oyetoro et al., 2016; Anonymous, 2023; Egbuta and Chima, 2022). The by-product of pawpaw juice production, known as pomace which consists of skin, seeds and pulp, is rich in protein, fibre, and other nutrients (Heuzé and Tran, 2015). Pawpaw pomace has not been extensively used in quails to ascertain its complementary impact on performance; some studies have shown the potential of pawpaw leaf (Ali et al., 2022; Inuwa et al., 2022), pawpaw peel (Leke et al., 2018) and pawpaw pomace in laying hens (Tamiru et al., 2021; Yildiz et al., 1998). This study aimed to investigate the impact of pawpaw pomace on egg production and quality in Japanese quails.

MATERIAL and METHOD

Ethical Consideration

This study adhered to the ethical guidelines set by the Ethical Committee of the Federal University, Gashua, Yobe State, Nigeria, regarding the use of animals in biomedical research (No: 02/2024).

Study Location

The study was conducted at the poultry unit of the teaching and research farms in the Faculty of Agriculture, Federal University, Gashua, Yobe State, Nigeria. It is on 12°, 52.547/12.8758°N and 11.0120°/11°00.719E. It is also located within the Sahel region of Nigeria with typical arid climate of high temperature, low rainfall and low humidity (Ovimaps, 2014).

Nutritional Composition of Pawpaw Pomace

Fresh pawpaw pomace was obtained from a private enterprise in in Jos, Plateau State, Nigeria and sun dried for five days on a clean concrete flow. The feed ingredients were separately ground in a hammer mill to pass a 3-mm sieve. The ground pawpaw pomace became pawpaw pomace meal (PPM). Chemical analyses were performed on the pomace to determine the proximate constituents and minerals content (AOAC, 2005), and amino acid profile (Beniter, 1989) and the results presented in Table 1.

Table 1. Chemical analysis of pawpaw pomace

Proximate constituents and energy (%DM)	Quantity
Crude protein	24,43
Crude fibre	16,60
Ether extract	3,17
Total ash	14,73
Nitrogen free extract	41,07
*Energy ($MJ.kg^{-1}$)	1230,79
Minerals (g/kg DM)	
Calcium	26,35
Phosphorus	4,81
Potassium	23,20
Sodium	15,0
Magnesium	6,75
Manganese	9,0
Zinc	6,0
Iron	86,1
Copper	7,1
Essential amino acids (%DM)	
Arginine	2,40
Histidine	2,85
Isoleucine	3,85
Leucine	6,20
Lysine	4,20
Methionine	1,85
Phenylalanine	3,25
Threonine	3,10
Valine	3,85

*Energy = (Crude protein x 17 + Ether extract x 37 + Nitrogen free extract x 17) (Kwari *et al.*, 2011)

Experimental Diet

A basal diet containing 22.43% crude protein and 2,888.60 kca/kg energy was formulated and designated as control. Three other dietary treatments were prepared by adding PPM at 2.5%, 5%, 7.5% and were designated as follows: PPM2.5: basal diet added with 2.5%PPM, PPM5: basal diet added with 5%PPM and PPM7.5: basal diet added with 7.5%PPM (Table 2).

Table 2. Ingredients and composition (%) of experimental diets used in the study

Ingredients (%)	Control	PPM2.5	PPM5	PPM7.5
Maize	42.50	42.00	41.50	38.50
Soybean meal	35.00	27.86	20.71	13.57
Pawpaw pomace	0.00	7.14	14.29	21.43
Wheat offal	5.00	4.00	3.00	3.00
Groundnut cake	7.00	8.00	9.00	12.00
Fish meal	2.00	2.50	3.00	3.00
Bone meal	3.00	3.00	3.00	3.00
Limestone	4.00	4.00	4.00	4.00
Premix	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25
Soy oil	0.50	0.50	0.50	0.50
Total	100.00	100.00	100.00	100.00
Nutrients (%)				
Crude protein	22.43	22.21	22.14	22.07
Energy (kcal/kg)	2,888.60	2,857.99	2,864.97	2,871.36
Lysine	1.05	1.08	1.06	1.02
Methionine	0.40	0.47	0.46	0.44
Calcium	2.91	2.92	2.93	2.94
Phosphorus	0.98	0.98	1.98	0.99
Crude fibre	4.36	4.42	4.43	4.50

Control: basal diet, PPM2.5: basal diet added with 2.5%PPM, PPM5: basal diet added with 5%PPM and PPM7.5: basal diet added with 7.5%PPM

Animal Material and Management

140 female quails at 28 days old by age were randomly selected from 400 quails which were reared at the poultry unit of the teaching and research in the Faculty of Agriculture, Federal University, Gashua. They were also randomly divided 4 treatment groups. Each treatment group had 35 quails and replicated 5 times with 7 quails per replicate.

A moving house constructed with wood and wires mesh with 5 tiers pen units (45x65cm each). Each pen unit housed 7 quails, feeder and drinker. Feeders with concave mouth were used to eliminate feed wastage. In the first three days the quails were administered 1 tea spoonful of glucose in every 4 litter of water and supplied with commercial grower mash for acclimatization. Thereafter they were given their respective treatment diets and ordinary water *ad libitum* for 8 weeks and the experiment was terminated when the quails were 87 days by age. Each pen was clean daily and mortality recorded as occurred.

Data Collection

Performance

Feed intake (FI) was determined weekly (Sudik, 2024). A known quantity of feed was supplied each day and the leftover in the following day was weight and subtracted from the supply to determine daily feed consumption. Cumulative daily feed consumed gave total feed intake (TFI) (Ezenwosu et al., 2024; Sudik et al., 2024a).
Thee eggs were randomly selected each replicate daily was and used to determine yolk and albumen quality.
Eggs were collected three times daily (morning, afternoon and evening) from the following variables were calculated as follows:
Hen-day-egg-production: HDEP

HDEP = $\frac{Total\ number\ of\ eggs\ laid\ on\ a\ day}{Total\ number\ of\ hens}\ X\ 100$ (Rizzi 2023).

Feed conversion ratio: FCR

FCR = $\frac{Kg\ of\ feed\ consumed}{Kg\ of\ egg\ produced}$ (Rizzi 2023).

Determination of Egg Quality

All the eggs in the first day of every week were collected carefully labeled and used to determine the quality parameters.
Egg weight: eggs were weighed per replicated using the same weighing scale
After taken the weight, the egg was cracked on a clean flat surface; the shell, yolk and albumen were carefully separated and weighed using digital scale with sensitivity of 0.01g. The yolk color was determined using the Roche Yolk Color Fan. Haugh unit: The formula used in calculating the Haugh unit is as follows:
Haugh unit = 100 * log (h + 7.57 - 1.7w^0.37) (Haugh, 1937).
Where:
h = height of the egg white in millimeters
w = weight of the egg in grams
The height of the yolk was measured by inserting a toothpick into the egg yolk on the highest surface then marking the height limit of the egg yolk on the toothpick, and then measured using a caliper. Cracked eggs: All eggs were candled to separate out the cracked and checked eggs. The sum of the cracked eggs was calculated as the percentage of total collected eggs on the same day. Eggshell weight: egg membrane was removed in every shell before drying in an oven at 65^{o}C for two days. The weight of dried shell was determined using the same digital scale. Shell thickness was

determined using a micrometer screw gauge after removing the egg membrane and dried in an oven (Sudik et al., 2024b).

Statistical Analysis

The data was analysed using IBM SPSS version 25 software with descriptive statistics, and one-way ANOVA was conducted on each parameter to determine differences in the means using Duncan's Multiple Range Test at a significance level of $p < 0.05$.

The following completely randomized design model was used to evaluate the production function:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:

Y_{ij} = individual observation

μ = Overall mean

Ti = Treatment effect (i=1, 2, 3, 4, 5)

e_{ij} = Random error

RESULTS and DISCUSSION

The study examined the impact of adding pawpaw pomace meal (PPM) to the diets of Japanese quails on their performance. The results in Table 3 revealed that hen-day-egg-production varied significantly (P<0.05) among the treatments, with 2.5% PPM and 5% PPM leading to the highest rates, followed by the control. However, hen-day-egg production decreased as the PPM levels increased to 7.5%. Additionally, 7.5% PPM resulted in higher total feed intake compared to the control, 2.5% PPM, and 5% PPM. This corroborates the report of Inuwa et al. (2022) who also observed higher egg production fed pawpaw leaf. Tamiru et al. (2021) reported improvement of egg production by 6.15% in laying hens fed 5% pawpaw pomace. However, Leke et al. (2018) used pawpaw peel and reported a higher value of 12%. This indicates that pawpaw peel is more tolerated than pawpaw pomace which consists of skin, seeds and pulp (Heuzé and Tran, 2015). Higher egg weight has been attributed deposition of lipid in egg yolk (Bohnzack et al., 2007; Grobas et al., 2001; Senkoylu et al., 2004). The higher feed intake in 7.5% PPM could be us to the higher crude fiber content in pawpaw pomace (Table 1) as compared to 6% in soybean meal (NIAS, 2021). Iheukwumere et al. (2008) opined that higher fiber in diet can depressed production. Egg weight was highest in the 5% PPM group, with a significantly (P<0.05) greater value compared to other diets, while 7.5% PPM had a lower egg weight. Feed conversion ratio followed a similar trend to egg weight, with 5% PPM showing the best ratio. The study also indicated that 5% PPM was the optimum level for laying quails. Similarly, Tamiru et al. (2022) reported negative impact of FCR when fed laying hens beyond 5% pawpaw pomace. Moreover, the results projected that quails could lay between 278-319 eggs annually going by the 77.14% to 88.57% hen-day-egg production, falling within the range of high-producing quails (Oluyemi and Roberts, 1979). The higher production could perhaps means the present inclusion levels were tolerated by the birds. This corroborates with Emmanuel (2018) who described pawpaw fruits containing lower anti-nutritional factors in comparison to commonly consumed fruits.

Table 3. Performance of laying Japanese quails fed diets containing graded levels of pawpaw pomace meal

Parameters	Control	PPM2.5	PPM5	PPM7.5	±SEM	P-value
Hen-day-egg production (%)	82.86^{ab}	85.71^{a}	88.57^{a}	77.14^{b}	9.34	0.031
Feed intake (g/hen per day)	20.43^{b}	20.25^{b}	20.14^{b}	21.55^{a}	0.82	0.008
Egg weight (g/egg)	9.19^{ab}	9.37^{ab}	10.03^{a}	8.31^{b}	0.79	0.024
Feed conversion ratio	2.22^{b}	2.15^{bc}	2.02^{bc}	2.59^{a}	0.30	0.011

Control: basal diet, PPM2.5: basal diet added with 2.5%PPM, PPM5: basal diet added with 5%PPM and PPM7.5: basal diet added with 7.5%PPM
Values with different superscript in the row are significantly different ($p<0.05$).

Regarding egg quality (Table 4), significant differences ($p<0.05$) were observed across different PPM levels, particularly in yolk color, yolk weight, albumen weight, and Haugh unit. Dark orange yolk color was noted in the test diets, which could be attributed to the high pro-vitamin A carotenoids in pawpaw fruit (Kumar et al., 2019).

Table 4. Egg quality of Japanese quails fed diets containing graded levels of pawpaw peel meal

Parameters	Control	PPM2.5	PPM5	PPM7.5	±SEM	P-value
Yolk color	7^{b}	8^{a}	8^{a}	8^{a}	0.41	0.018
Yolk weight (g)	2.85^{b}	2.9^{a}	3.11^{a}	2.58^{c}	0.24	0.037
Albumen weight (g)	5.33^{ab}	5.53^{a}	5.82^{a}	4.82^{b}	0.46	0.0.045
Albumen height (mm)	7	7	7	7	0.00	0.998
Haugh unit	92.97^{a}	92.86^{a}	94.45^{a}	89.54^{b}	0.50	0.010
Eggshell weight (g)	1.01	1.03	1.1	0.89	0.09	0.617
Eggshell thickness (mm	0.3	0.3	0.3	0.3	0.00	0.947
Cracked eggs/T/d (%)	0	0	0	0	0	-

Control: basal diet, PPM2.5: basal diet added with 2.5%PPM, PPM5: basal diet added with 5%PPM and PPM7.5: basal diet added with 7.5%PPM
Values with different superscript in the row are significantly different ($p<0.05$)

Leke et al. (2018) reiterated that the main factor that affects the color of the yolk is the pigment. The study highlighted that as the PPM level increased from 2.5% to 5%, there was a direct improvement in egg quality characteristics, a similar finding was reported by Inuwa et al. (2022) when fed pawpaw leaf. Conversely, 7.5% PPM had a negative effect on egg quality characteristics. The findings suggested that 5% PPM in the diet could enhance quail performance and egg quality, making it a beneficial choice for these birds. The similarity in eggshell weight and eggshell thickness has also reported by Senkoylu et al. (2005) indicating all the diets contained the required calcium and phosphorus contents. These two elements are responsible to eggshell formation and strengthening (John et al., 2012).

CONCLUSION

This research found that increasing PPM from 2.5% to 5% in quail diets improved egg production metrics, but increasing it further from 5% to 7.5% had a negative impact. Therefore, it can be deduced that a 5% PPM in quail diets improves egg production and quality without adverse effects. Moreover, reducing soybean meal by 5% PPM can help lower feed costs.

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Authors' contribution

Conceptualization, SSD; methodology, SSD, AM; investigation, SSD; data curation, , ZAM; writing original draft preparation, SSD; writing, SSD; review and editing, SSD, ZAM, AM; project administration, SSD, ZAM, AM. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

We declare no conflicts of interest.

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