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# EFFECT OF DIETARY INCLUSION OF QUINOA SEED ON PRODUCTIVITY, EGG QUALITY AND INTERNAL ORGAN TRAITS IN QUAILS

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***Abstract***

*This study examined the effects of dietary quinoa seed (Chenopodium quinoa Willd.) supplementation on production performance, egg quality and internal organ traits in Japanese quails (Coturnix coturnix japonica). A total of 90 six-week-old quails were randomly divided into three groups: a control group and two treatment groups receiving diets supplemented with 5% and 10% quinoa seeds, respectively. Over a 8-week trial, key performance indicators were evaluated, including egg weight, feed conversion ratio, internal organ development, and egg quality traits. Results indicated that 5% quinoa inclusion significantly improved egg weight, feed conversion ratio, and small intestine development (P<0.05). Additionally, both quinoa-supplemented groups showed enhanced yolk pigmentation, with increased yellowness (b) and lightness (L), but a decrease in yolk index. No adverse effects were observed on overall egg production, feed intake, or internal organ weights (P>0.05). These findings suggest that quinoa, particularly at 5% inclusion, is a valuable feed additive for enhancing quail productivity and egg quality without compromising health or performance, supporting its use as a functional and sustainable alternative ingredient in poultry nutrition.*

***Key words****: egg quality traits, Japanese quails, quinoa seed, production performance.*

## INTRODUCTION

Recent years have witnessed growing interest in the use of alternative feed ingredients in poultry nutrition. driven by the need for sustainable cost-effective and nutritionally rich options. One such promising alternative is *Chenopodium quinoa* (quinoa), a pseudocereal renowned for its rich nutrient composition, including high-quality protein, essential amino acids, unsaturated fatty acids, vitamins. minerals and antioxidants (Vega-Gálvez et al., 2010). Native to the Andean regions of Bolivia, Chile and Peru. quinoa is also cultivated in southern parts of Iran as a potential protein source in animal feeding systems (Amiri et al., 2021). The interest in utilizing alternative protein sources like quinoa in poultry diets has grown substantially. Quinoa stands out due to its richness in essential amino acids such as lysine and methionine and its notable content of water-soluble vitamins including riboflavin, thiamine and niacin. It is also a good source of minerals such as manganese, iron, potassium, copper. zinc and phosphorus (Amiri et al., 2021). Compared to conventional cereals such as corn, barley, wheat and oats. Quinoa contains higher levels of metabolizable energy, calcium, iron, phosphorus and vitamins B and E (Vilche et al., 2003; Konishi et al., 2004). Despite these advantages quinoa also contains certain anti-nutritional compounds such as saponins, phytates, and trypsin inhibitors, which may negatively affect nutrient absorption in monogastric animals like poultry (Oboh & Elusiyan, 2007). Therefore, its inclusion in poultry diets must be approached with consideration for these factors. Studies have demonstrated that applying various processing techniques to quinoa can enhance its digestibility, thereby promoting better nutrient absorption and increased body weight in poultry (Eassawy et al., 2016). Furthermore, quinoa seed extract contains high levels of phenolic and antioxidant compounds, which are associated with improved growth performance and feed efficiency. The incorporation of bioactive-rich functional ingredients like quinoa into poultry diets has also been shown to enhance various egg quality traits - such as yolk pigmentation, shell strength, and albumen height - primarily due to the presence of beneficial compounds like flavonoids and saponins (González et al., 2012; Repo-Carrasco-Valencia & Serna, 2011). Moreover, dietary modifications can significantly affect avian reproductive physiology by influencing ovarian development, follicular growth, and hormonal regulation (Saki et al., 2011). While studies on broilers have shown that quinoa seed supplementation can enhance body weight gain and improve feed conversion ratios (Nokandi et al., 2021), research specifically focusing on the effects of quinoa inclusion on laying performance, egg quality, and reproductive organ development in quails (*Coturnix coturnix japonica*) - a species recognized for its high egg production and efficient feed utilization - remains limited. Accordingly, this study aims to assess the effects of dietary quinoa seed supplementation on productivity egg quality and internal organ traits in laying quails. The results are anticipated to address significant gaps in the existing literature and provide evidence-based insights to enhance the sustainability and efficiency of quail nutrition strategies.

## MATERIALS AND METHODS

This study was conducted following ethical guidelines and was approved by the Dicle University Experimental Animal Ethics Committee (DÜHADEK) under protocol number 2023/21.

This experiment was carried out at the Poultry Research and Application Unit of Dicle University. Ninety six-week-old Japanese quails *(Coturnix coturnix japonica),* housed in cages at a ratio of one male to two females, were randomly assigned to three dietary treatment groups, each consisting of 10 replicates. The study spanned a 10-week period. The experimental design included: (1) a control group fed a standard basal diet, and (2) two treatment groups receiving the same basal diet supplemented with either 5% or 10% quinoa seed. All diets were formulated to meet the nutritional requirements specified by the National Research Council (NRC, 1994), ensuring a consistent basal composition across all groups (Table 1). The experimental diets were formulated to ensure comparable levels of protein and energy. The proximate composition of the diets was determined using standard analytical procedures as outlined by the Association of Official Analytical Chemists (AOAC, 2005). Nutrient contents. including crude protein, crude fat, crude ash, fiber, calcium and phosphorus were calculated to meet the nutritional requirements of laying quails.

Table 1. Ingredients and chemical composition of the experimental diets

| Ingredients | % | | |
|---|---|---|---|
| | Quinoa 0 (Control) | Quinoa 5 | Quinoa 10 |
| Sunflower oil | 2.20 | 2.00 | 2.00 |
| Maize | 58.00 | 54.20 | 50.20 |
| Soybean Meal (44%. CP) | 22.00 | 21.00 | 22.00 |
| Sunflower Meal (32%. CP) | 8.00 | 8.00 | 8.00 |
| Quinoa seeds | - | 5.00 | 10.00 |
| Dicalcium Phosphate[a] | 2.00 | 2.00 | 2.00 |
| Limestone | 7.00 | 7.00 | 7.00 |
| DL-Methionine | 0.15 | 0.15 | 0.15 |
| NaCl | 0.30 | 0.30 | 0.30 |
| Vitamin and Mineral Premix[b] | 0.25 | 0.25 | 0.25 |
| **Items** | **Analyzed values, %** | | |
| Dry Matter | 90.3 | 90.3 | 90.3 |
| Crude Protein | 17.1 | 17.1 | 17.1 |
| Ether extract | 4.12 | 4.12 | 4.10 |
| Crude Ash | 12.12 | 12.14 | 12.15 |
| Crude Fiber | 3.90 | 3.89 | 3.87 |
| **Items** | **Calculated values, %** | | |
| Metabolizable energy (ME). kcal/kg | 2750 | 2750 | 2750 |
| Calcium | 3.24 | 3.24 | 3.24 |
| Available Phosphorus | 0.44 | 0.44 | 0.44 |
| Na | 0.17 | 0.17 | 0.17 |
| Cl | 0.23 | 0.23 | 0.23 |
| Methionine + Cysteine | 0.70 | 0.70 | 0.70 |
| Lysine | 0.87 | 0.87 | 0.87 |
| Threonine | 0.61 | 0.59 | 0.59 |
| Tryptophan | 0.23 | 0.22 | 0.22 |
| Linoleic acid | 2.17 | 2.16 | 2.16 |
| Electrolyte Balance (mEq/kg DM) | 194 | 192 | 192 |

[a]Composition: 240 g Ca and 17.5 g P/kg; [b]Vit+Min. Mineral mixture provides the following nutrients per kg of diet: vitamin A: 12.000.000 IU; vitamin D3: 2.500.000 IU; vitamin E: 30 ppm; vitamin K3: 4.000 ppm; vitamin B1: 3.000 ppm; vitamin B2: 7.000 mg; vitamin B12: 5.000 ppm; vitamin C: 50.000 ppm; Biotin: 45 ppm; folic acid: 1.000 ppm; Fe

The control group was fed a basal diet without quinoa supplementation. whereas the treatment groups received diets supplemented with 5% and 10% quinoa seeds respectively. The experimental period lasted for eight weeks, during which relevant data were systematically recorded. The study evaluated parameters including egg quality, feed intake, feed conversion ratio, internal organ weights.

Throughout the experimental period a lighting schedule of 16 hours light and 8 hours dark (16L:8D) was maintained. Feeders were manually refilled daily and eggs were collected each morning. At the onset of the trial, hens were individually weighed and allocated to cages based on similar body weights and egg production levels to ensure uniformity across treatment groups. Feed intake, egg production and egg weight were recorded daily while feed conversion ratio and other performance parameters were calculated on a weekly basis.

During the analysis phase. a total of 30 eggs were evaluated each week with one egg randomly selected from each cage. Eggs were collected from each group over two consecutive mornings. stored overnight at 4°C and subsequently subjected to both external and internal quality assessments. By the conclusion of the experiment. a total of 240 eggs had been analyzed.

Specific gravity was determined by weighing each egg after a one-day storage period under ambient conditions, followed by immersion in water at 22°C and subsequent reweighing in accordance with the method outlined by Hempe et al. (1988). Yolk colour was evaluated using a digital colorimeter (Minolta CR-300) with measurements expressed as L, a, and b values. Albumen height was measured using a digital micrometer and subsequently used to calculate the albumen index using the formula: [albumen height (mm) / ((albumen length (mm) + albumen width (mm)) / 2)] × 100.

At the end of the experiment, 10 female quails from each experimental group (one bird per replicate) were randomly selected to determine internal organ weights. The birds were euthanized in accordance with ethical guidelines, and careful dissection was performed starting from the breastbone to open the abdominal cavity. Non-carcass internal organs such as the liver, heart, spleen, pancreas, kidneys, and abdominal fat tissue were carefully excised. After removal, any excess fluids and residues on the organs were cleaned to prevent contamination before weighing. Each organ was weighed immediately using a precision balance. Relative internal organ weights were calculated using the formula: "Organ Weight (g) / Live Body Weight (g) × 100".

Data were subjected to one-way analysis of variance (ANOVA) using SPSS software (version 18.0; IBM Corp. Armonk. NY. USA). When significant differences were detected. treatment means were compared using Tukey's multiple comparison test at a significance level of *P*<0.05. Additionally. regression analysis was conducted to evaluate linear. quadratic. and cubic trends in response to varying levels of mealworm inclusion.

## RESULTS AND DISCUSSIONS

Table 2 evaluates the effects of dietary quinoa seed inclusion at 0%, 5%, and 10% on the productivity performance of Japanese quails. The 5% quinoa group recorded significantly higher egg weights compared to the control and 10% quinoa groups (*P*< 0.01). In addition, both 5% and 10% quinoa groups had improved FCR compared to the control (*P*<0.05). However, egg Production and Daily Feed Intake: These parameters did not significantly differ across groups (*P* > 0.05). The improvement in egg weight and FCR with 5% quinoa aligns with the nutrient-rich profile of quinoa, particularly its high-quality protein and balanced amino acid content (Amiri et al., 2021). Quinoa is also rich in essential amino acids such as lysine and methionine, which are critical for egg formation and overall productivity (Vega-Gálvez et al., 2010). The enhanced FCR indicates better nutrient utilization, likely influenced by quinoa's bioactive compounds including flavonoids and antioxidants. These components have been shown to promote gut health and improve metabolic efficiency, as supported by Nokandi et al. (2021) who reported improved performance in broilers fed quinoa-based diets. Interestingly, the 10% inclusion did not yield further improvements and slightly reduced egg weight compared to 5%, suggesting a threshold effect beyond which no additional benefits occur - possibly due to anti-nutritional factors such as saponins and phytates, known to impair nutrient absorption in monogastrics (Oboh & Elusiyan, 2007). This highlights the importance of optimal inclusion levels to balance benefits with potential drawbacks. Moreover, the non-significant differences in egg production and feed intake across groups support previous findings that quinoa does not negatively affect laying rate or appetite (Naïmatî et al., 2022), thus maintaining reproductive performance while enhancing efficiency. Quinoa inclusion at 5% appears to be optimal, enhancing egg weight and feed efficiency without compromising overall productivity. This supports quinoa's role as a sustainable and functional ingredient in poultry nutrition, corroborated by previous research on its positive impacts on performance and intestinal health (Eassawy et al., 2016; González et al., 2012).

The findings in Table 3 illustrate the influence of different dietary levels of quinoa seeds on the egg quality traits of Japanese quails. Notably, while most traits such as shell weight, shell thickness, shape index, and albumen index were statistically non-significant (P>0.05), yolk-related characteristics and colorimetric values revealed meaningful variation among treatments. The yolk index significantly decreased with quinoa supplementation, with the control group showing the highest value compared to the 5% and 10% quinoa groups (P < 0.001). This finding is contrary to expectations based on the antioxidant and lipid profile of quinoa, which are generally associated with yolk structural integrity (González et al., 2012; Repo-Carrasco-Valencia & Serna, 2011). The reduction may stem from structural changes in yolk composition due to quinoa's saponin content, which has been known to influence nutrient absorption (Oboh & Elusiyan, 2007). In terms of yolk coloration, the lightness (L), redness (a), and yellowness (b) values were all significantly altered by quinoa inclusion. The 5% quinoa group exhibited the highest L value indicating lighter yolks compared to control and 10% (P<0.01). Redness (a) was significantly lower in the 5% group than in the control (P <0.05), whereas yellowness (b*) was significantly higher in both quinoa groups compared to the control (P<0.01). These results align with previous reports that flavonoids and carotenoids in quinoa enhance yolk pigmentation, particularly increasing b values indicative of a deeper yellow hue (Vilche et al., 2003; Amiri et al., 2021).

Other quality traits such as specific gravity and shell characteristics showed no significant changes, suggesting that quinoa supplementation at up to 10% does not compromise shell integrity. This stability is crucial for commercial egg production, where shell robustness affects transport and storage quality (Hempe et al., 1988). Overall, these results support earlier research demonstrating the potential of quinoa as a natural pigment enhancer and nutrient-dense feed additive in poultry diets (Eassawy et al., 2016; Nokandi et al., 2021). However, the decline in yolk index prompts further study into the biochemical interactions of quinoa components within avian physiology.

Table 4 presents the effects of different dietary quinoa seed levels on the relative weights of non-carcass internal organs in female Japanese quails. Among the measured organs, only the small intestine showed a statistically significant response (P<0.01) to quinoa inclusion, whereas the heart, liver, abdominal fat, stomach, gizzard, cecum, and large intestine weights were unaffected (P > 0.05). The small intestine weight was significantly higher in the 5% and 10% quinoa groups compared to the control, suggesting enhanced intestinal development with quinoa supplementation. This result is in line with findings from Eassawy et al. (2016), who reported improved intestinal morphology and nutrient absorption in poultry following inclusion of antioxidant-rich feed components like quinoa. The enhanced gut development may be attributed to quinoa's bioactive compounds, including polyphenols and flavonoids, known to promote gut health and modulate microbiota composition (Repo-Carrasco-Valencia & Serna, 2011). The lack of significant change in liver and abdominal fat weights indicates that quinoa supplementation does not adversely affect lipid metabolism or fat deposition. This is consistent with findings by Nokandi et al. (2021), where dietary quinoa did not alter fat pad weights in broilers, likely due to its favorable fatty acid composition and presence of saponins, which can reduce lipid absorption. Interestingly, the weights of digestive organs such as the stomach and gizzard were also unaffected. This suggests that quinoa inclusion at the tested levels does not impair digestive organ development or function. Similarly, unchanged cecum and large intestine weights point to the maintenance of hindgut health and fermentation capacity, supporting the use of quinoa as a gut-friendly feed ingredient. Collectively, the results indicate that dietary quinoa, particularly at 5%, promotes intestinal development without negatively impacting other internal organs. These findings further support quinoa’s potential as a functional feed additive that can enhance nutrient utilization in quails without compromising visceral health, aligning with previous reports emphasizing quinoa's high digestibility and nutritional quality (Amiri et al., 2021; González et al., 2012).

Table 2. Productivity Performance of Quails Fed Diets Containing Varying Levels of Quinoa Seed

| Measurements | Quinova levels (%) | | | | | Effects[1] | | |
|---|---|---|---|---|---|---|---|---|
| | 0 (Control) | 5 | 10 | SEM[2] | *P-value* | L | Q | C |
| Egg Weight (EW), g | 13.1[b] | 13.6[a] | 13.3[ab] | 0.060 | 0.002 | NS | ** | ** |
| Egg Production. % | 87.6 | 85.3 | 82.2 | 1.340 | 0.248 | NS | NS | NS |
| Feed Intake (FI), g/quail/day | 42.0 | 41.9 | 40.8 | 0.380 | 0.338 | NS | NS | NS |
| Feed Conversion Rate (FI/EW) | 3.22[a] | 3.08[b] | 3.06[b] | 0.029 | 0.049 | ** | ** | ** |

[a,b]Means within each period with different superscript letters are significantly different (P < 0.05)
[1]Effects: L=Linear; Q= quadratic; C=cubic; [2]SEM = pooled standard error of the mean; NS = not significant.

Table 3. Egg quality traits of quails Fed Diets Containing Varying Levels of Quinoa Seed

| Measurements | Quinova levels (%) | | | | | Effects[1] | | |
|---|---|---|---|---|---|---|---|---|
| | 0 (Control) | 5 | 10 | SEM[2] | P | L | Q | C |
| Specific Gravity | 1.065 | 1.065 | 1.065 | 0.0004 | 0.974 | NS | NS | NS |
| Shell weight, g | 1.458 | 1.526 | 1.458 | 0.015 | 0.117 | NS | NS | NS |
| Egg Shell Rate | 10.87 | 10.95 | 10.85 | 0.106 | 0.919 | NS | NS | NS |
| Shell Thickness, mm | 0.334 | 0.321 | 0.309 | 0.008 | 0.515 | NS | NS | NS |
| Shape Index | 77.3 | 77.0 | 77.8 | 0.274 | 0.452 | NS | NS | NS |
| Albumen Index | 19.06 | 19.71 | 19.44 | 0.169 | 0.307 | NS | NS | NS |
| Yolk Index | 49.28[a] | 45.41[b] | 44.41[b] | 0.516 | <0.001 | ** | ** | ** |
| L* | 44.26[b] | 46.65[a] | 45.53[ab] | 0.331 | 0.011 | NS | ** | ** |
| a** | 22.8[a] | 21.6[b] | 22.01[b] | 0.201 | 0.029 | ** | ** | ** |
| b**** | 32.5[b] | 34.5[a] | 33.8[a] | 0.317 | 0.009 | ** | ** | ** |

[a,b]Means within [each] period with different superscript letters are significantly different (P < 0.05)
[1]Effects: L=Linear; Q= quadratic; C=cubic; [2]SEM = pooled standard error of the mean; NS = not significant;
L*: lightness; a**: redness; b***: yellowness.

Table 4. The relative weight of non-carcass part and internal organ traits of female quails fed quinoa seed-based diets

| Weights of Internal Organs, % | Quinova levels (%) | | | | | Effects[1] | | |
|---|---|---|---|---|---|---|---|---|
| | 0 (Control) | 5 | 10 | SEM[2] | P | L | Q | C |
| Heart Weight | 0.665 | 0.658 | 0.572 | 0.041 | 0.615 | NS | NS | NS |
| Liver Weight | 2.352 | 1.821 | 2.101 | 0.113 | 0.161 | NS | NS | NS |
| Abdominal Fat Pad | 2.072 | 1.624 | 2.152 | 0.220 | 0.594 | NS | NS | NS |
| Proventriculus | 0.222 | 0.260 | 0.272 | 0.021 | 0.619 | NS | NS | NS |
| Gizzard | 1.821 | 1.548 | 1.971 | 0.099 | 0.214 | NS | NS | NS |
| Small Intestine | 1.927[b] | 2.314[a] | 2.304[a] | 0.064 | 0.010* | NS | NS | NS |
| Cecum | 0.457 | 0.278 | 0.381 | 0.075 | 0.150 | NS | NS | NS |
| Large Intestine | 0.135 | 0.268 | 0.168 | 0.045 | 0.090 | NS | NS | NS |

[a,b]Means within each period with different superscript letters are significantly different (P < 0.05)
[1]Effects: L=Linear; Q= quadratic; C=cubic; [2]SEM = pooled standard error of the mean; [3]NS = not significant.

## CONCLUSIONS

This study demonstrated that dietary inclusion of quinoa seeds at 5% and 10% levels in quail diets can enhance certain productive and physiological parameters without adverse effects. Specifically, 5% quinoa supplementation significantly improved egg weight, feed conversion ratio, and small intestine development. Additionally, both quinoa levels enhanced yolk pigmentation, particularly increasing yellowness (b), while maintaining shell quality and other internal organ traits. These findings suggest that quinoa seeds represent a valuable, sustainable alternative protein and functional ingredient in quail nutrition, contributing positively to productivity and egg quality.

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