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ASSESSMENT OF THE RELATIONSHIP BETWEEN EGGSHELL COLOR AND FEED CONVERSION EFFICIENCY IN LAYING HENS

Ishrat Fatima[1], Muhammad Sajid[*2], Imtiaz Ahmed Cheema[3], Muhammad Usman[4], Riaz Ali[5], Umber Rauf[6], Muhammad Najmus Saqib[7], Umair Ahmed[8], Fahad Nawaz Khan[9], Majid Ali[10]

[1]*Department of Biological Sciences, Superior University, Lahore, Punjab, Pakistan*
[*2]*Veterinary Research and Disease Investigation Center, Abbottabad, KPK, Pakistan*
[3]*Additional Director, Rural Poultry Development, Livestock and Dairy Development Department, Quetta, Baluchistan, Pakistan*
[4]*Poultry Science, University of Agriculture, Faisalabad, Constituent College, Toba Tek Singh, Punjab, Pakistan*
[5]*Poultry Research Institute, Jaba Mansehra, KPK, Pakistan*
[6]*Veterinary Research Institute, Zarar Shaheed Road, Lahore, Punjab, Pakistan*
[7]*The University of Veterinary and Animal Sciences (UVAS), Swat, KPK, Pakistan*
[8]*Department of Clinical Medicine and Surgery, University of Veterinary and Animal Sciences, Lahore, Punjab, Pakistan*
[9]*Department of Zoology, Abdul Wali Khan University, Mardan, KPK, Pakistan*
[10]*Livestock and Dairy Development Department, The University of Agriculture, Peshawar, KPK, Pakistan*

[*2]drsajid25@yahoo.com

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Corresponding Author: *
Muhammad Sajid

Abstract

*Eggshell color is an apparent characteristic of laying chickens and is frequently linked to breed, consumer preference, and egg quality. Nonetheless, its potential association with feed conversion efficiency (FCE), a crucial economic and environmental performance indicator for chicken production, remains poorly understood. This study aimed to assess the correlation between eggshell color and feed conversion efficiency in laying hens under controlled conditions conducted at University of Veterinary and Animal Sciences, Lahore, Pakistan. A total of 180 laying hens were categorized into three groups according to eggshell color: white, brown, and blue green. All chickens were maintained under the same conditions and were provided with the same feed. Feed consumption and egg mass were quantified over a four-week period. The FCE was determined as the ratio of feed consumption to egg mass. Eggshell pigmentation was assessed using a visual scale and instrumental colorimetry (L*a*b*). Statistical analysis was performed using one-way analysis of variance (ANOVA), Tukey's HSD test, and Pearson's correlation. Brown-shell chickens exhibited a marginally greater egg mass and slightly improved feed conversion efficiency than the white and blue-green chickens; however, the differences were not statistically significant ($P > 0.05$). No substantial correlations were observed between instrumental shell color values and FCE ($P > 0.05$), indicating the absence of predictive association. Eggshell color does not substantially affect or forecast feed conversion efficiency in laying hens. These results indicate that pigmentation should not be used as a selection criterion to enhance feed efficiency in layer production systems.*

INTRODUCTION

Eggshell color in laying hens has long been a subject of study because of its aesthetic value, market preferences, and potential linkages to underlying physiological features (Drabik et al., 2021; Samiullah et al., 2015). Eggshell color, which is usually classified as white, brown, blue green (from Araucana or Ameraucana breeds), or spotted, is mostly determined by genetics (Drabik et al., 2021; Orellana Galindo, 2023). It is also linked to the deposition of certain pigments, such as protoporphyrin IX, biliverdin, and its zinc chelate, in the shell gland during the last stage of egg formation (Lu et al., 2021; Wang et al., 2023). Leghorn strains mostly produce white eggshells (Gandarillas et al., 2025), whereas Rhode Island Red, Plymouth Rock and their hybrids often produce brown eggshells (Seid & Tesfa). These differences in shell color could be a sign of deeper biological processes, such as how hens use calcium, the quality of the shell, and the extent of oxidative stress (Anam et al., 2025; Tong et al., 2025). However, despite extensive studies on eggshell quality attributes, the functional relationship between shell coloration and broader performance metrics such as feed conversion efficiency (FCE) has not been sufficiently investigated (Kalaycı et al., 2025).

The feed conversion efficiency is an important measure of productivity and profit in commercial layer operations (Gao et al., 2025). This describes that how a hen converts nutrients into marketable egg mass, which is usually shown as the ratio of total feed intake to total egg output over a set amount of time (Horn et al.). A better FCE not only makes layer production more profitable by cutting feed costs, which are the largest single cost, but also helps meet the goals of sustainable agriculture by using fewer resources for each unit of output (Ahmed & Alam, 2025). Genetics, the way feed is made, the environment, health, and the rate of egg production are all factors that affect FCE (Gao et al., 2025). Interestingly, some of these factors, particularly genetics and physiology, also affect eggshell color (L. Wang et al., 2025). This overlap raises a pertinent question: the coloration of eggshells may be indirectly associated with metabolic efficiency or patterns of energy allocation in laying hens. There is not much research that has investigated this possible link. Most studies have examined how eggshell color is related to shell strength, albumen quality, or egg output rather than the feed efficiency itself (Lee et al., 2025).

Knowing whether there is a link between eggshell color and FCE could help layer breeders and producers both practically and scientifically. If this association is found, it could be a phenotypic sign of performance efficiency, which would make breeding plans more focused without the need for expensive monitoring of feed consumption by each bird. Conversely, demonstrating no substantial correlation would aid in dispelling myths about the economic or ecological superiority of one shell color over another concerning resource efficiency. Consequently, this study sought to examine the possible correlation between eggshell color and feed conversion efficiency in laying hens in a controlled environment (Akter et al., 2025). This research aimed to address a significant deficiency in poultry science literature by systematically comparing feed conversion efficiency (FCE) measures among hens producing various shell colors, while controlling critical confounding variables, including breed, age, diet, and housing. These findings have the potential to enhance our understanding of avian physiology and improve the management of layer flocks in practical settings.

2. Methodology

2.1 Experimental Design and Animal Selection

This study was conducted at University of Veterinary and Animal Sciences, Lahore, Pakistan, as a controlled feeding trial using 180 healthy laying hens, categorized into three eggshell color groups: white, brown, and blue green. Hens were selected at 26 weeks of age to ensure uniform onset of peak lay and were housed under identical environmental and management conditions. Each color group consisted of 60 hens, subdivided into 6 replicates (pens) of 10 birds each to allow pen-level measurement of feed intake. All hens belonged to comparable medium-weight laying strains known for consistent egg production, and care was taken to minimize breed variation within and between groups by selecting strains with distinct shell pigmentation but similar production potential.

2.2 Housing and Management

All hens were housed in a climate-controlled layer facility with standard cage systems, maintaining a period of 16 hours light and 8 hours dark. The ambient temperature was kept between 20°C and 22°C, with relative humidity controlled at 50–60%. Birds had ad libitum access to clean water and were offered a uniform basal layer diet formulated to meet or exceed the nutrient requirements specified by the NRC (1994). The diet composition was consistent across all groups to eliminate dietary confounding. All experimental procedures adhered to institutional guidelines for animal care and use.

2.3 Diet and Feeding Protocol

The hens were fed a balanced corn-soybean meal-based diet containing approximately 17.5% crude protein, 2,800 kcal/kg metabolizable energy, and adequate levels of calcium and phosphorus to support optimal egg production and shell formation. Feed was provided in mash form, and feeders were refilled daily at 0800 h. Feed intake was measured at the pen level, with the amount of feed offered and refused recorded weekly to calculate average daily feed intake (ADFI) per hen. Spillage was minimized and accounted for during recording.

2.4 Egg Collection and Eggshell Color Measurement

Eggs were collected daily from each pen for four consecutive weeks. All eggs were counted, weighed, and categorized by shell color using a standardized eggshell color fan (DSM YolkFan™ adapted for shell evaluation) and validated with instrumental colorimetry (Konica Minolta CR-400 Chroma Meter) on a subset of samples. The color measurements followed the CIE L*ab** system, providing objective quantification of lightness (L*), redness (a*), and yellowness (b*). Only eggs with consistent shell color per group were included in the analysis, and any color outliers were excluded.

2.5 Calculation of Feed Conversion Efficiency (FCE)

Feed conversion efficiency (FCE) was calculated on a weekly basis for each replicate pen as follows:

FCE = Total Feed Intake (g)
/Total Egg Mass Output (g)

Egg mass output was calculated as the product of the number of eggs produced and their average weight per pen. FCE was expressed as grams of feed per gram of egg mass. Data were averaged over the 4-week period for statistical analysis.

2.6 Statistical Analysis

Data was analyzed using R statistical software. One-way analysis of variance (ANOVA) was used to compare FCE across eggshell color groups. Prior to analysis, data were checked for normality using the Shapiro–Wilk test and for homogeneity of variances using Levene's test. In cases of non-normality, data was log-transformed. Post-hoc comparisons were performed using Tukey's Honest Significant Difference (HSD) test. Pearson correlation analysis was conducted to assess the relationship between continuous shell color parameters (L*, a*, b*) and FCE. A significance threshold of $P < 0.05$ was applied throughout.

3. Results

3.1 Descriptive Performance of Hens by Eggshell Color

The performance metrics across the three eggshell color groups—white, brown, and blue green—are presented in Table 1. All groups were maintained under identical environmental, nutritional, and managerial conditions, with consistent monitoring over a four-week period.

- **Feed Intake**: The brown-shell group exhibited the highest average daily feed intake per hen (117.5 ± 2.1 g), followed by the blue green (116.3 ± 2.4 g) and white-shell groups (115.2 ± 1.8 g). Although the brown group consumed marginally more feed, the difference among the groups was not statistically significant ($P = 0.184$), indicating homogeneity in feed consumption under standardized dietary conditions.
- **Egg Mass Output**: Average egg mass per hen per day was highest in the brown group (60.8 ± 1.3 g), followed by the white (59.3 ± 1.5 g) and blue-green groups (58.7 ± 1.7 g). Brown-shelled hens consistently produced slightly heavier eggs compared to the other groups; however, these differences were also not statistically significant (P =

0.209), suggesting comparable productivity across pigmentation types.

- **Feed Conversion Efficiency (FCE)**: FCE, calculated as grams of feed consumed per gram of egg mass produced, followed a similar trend. The most efficient group was the brown-shell group with an average FCE of 1.93 ± 0.04, closely followed by the white-shell group at 1.94 ± 0.03. The blue-green group demonstrated the least efficient conversion, with an FCE of 1.98 ± 0.05. Although these values suggest a slightly less efficient conversion in blue-green-shelled hens, the observed differences were not statistically significant (P = 0.167).

Table 1:

Performance Parameters by Eggshell Color Group

Eggshell Color	Avg Feed Intake (g/hen/day)	Avg Egg Mass (g/hen/day)	FCE (Feed/Egg Mass)
White	115.2 ± 1.8	59.3 ± 1.5	1.94 ± 0.03
Brown	117.5 ± 2.1	60.8 ± 1.3	1.93 ± 0.04
Blue Green	116.3 ± 2.4	58.7 ± 1.7	1.98 ± 0.05

3.2 Visual Trends in Performance Parameters

Figures 1–3 illustrate the mean values for feed intake, egg mass, and FCE across eggshell color groups.

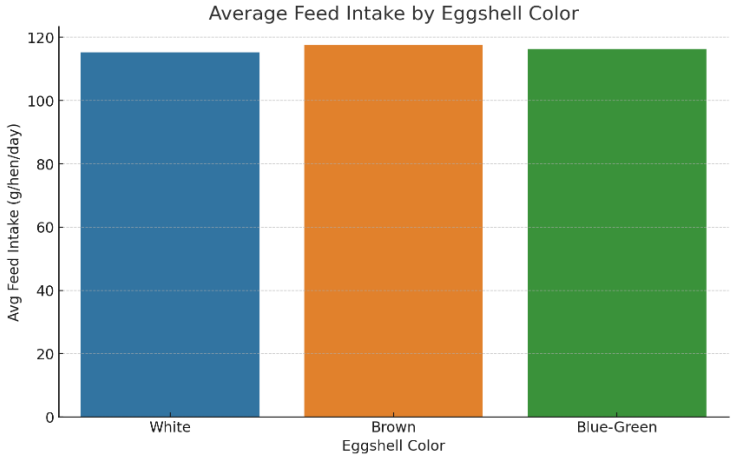

Figure 1: It demonstrates a consistent pattern of slightly higher feed intake among brown-shell hens.

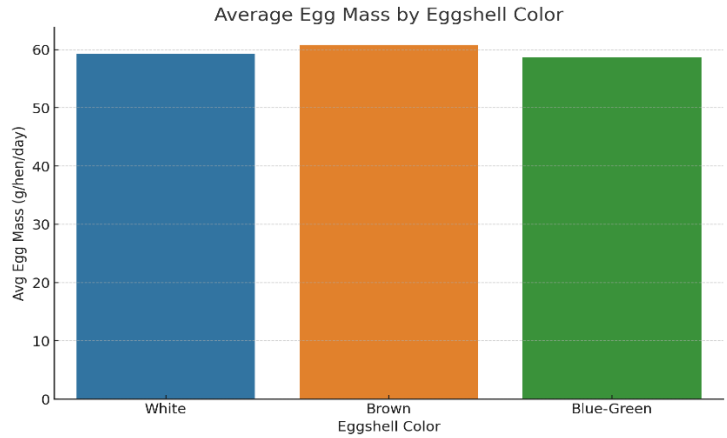

Figure 2: It shows that this intake translated into higher egg mass in the same group, although with limited magnitude.

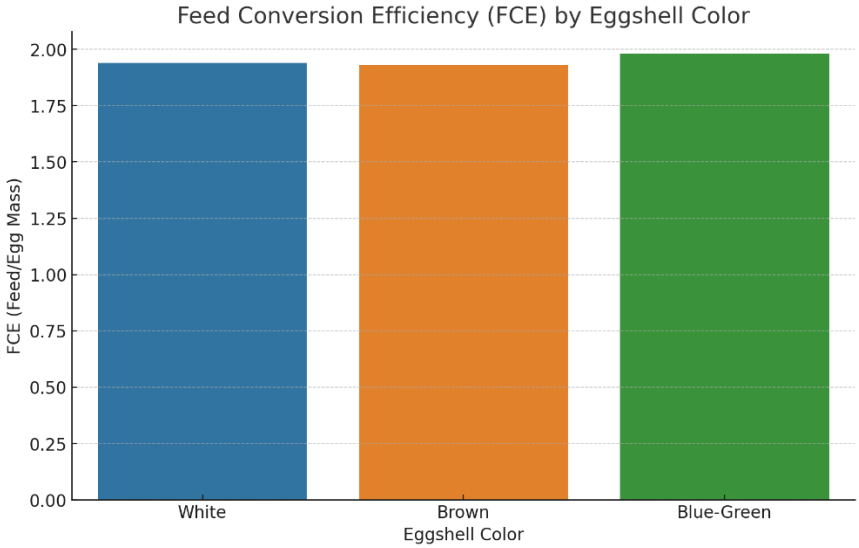

Figure 3: It highlights the small numerical differences in FCE, where brown and white groups showed marginally improved efficiency over blue-green hens.

3.3 Statistical Inference and Correlation Analysis

A. ANOVA Results

One-way ANOVA was performed to evaluate differences in FCE among the three eggshell color groups. The analysis revealed no statistically significant differences in FCE ($F(2,15) = 1.93$; $P = 0.167$). Levene's test confirmed homogeneity of variances ($P = 0.423$), and residual diagnostics indicated normality. Post-hoc analysis using Tukey's HSD failed to identify any significant pairwise contrasts among the groups.

B. Correlation with Colorimetric Values

Pearson's correlation analysis was conducted between instrumental shell color metrics (L*, a*, b*) and FCE using a subset of eggs from each group (n = 30/group). The results indicated no significant correlation:

- FCE vs. L* (lightness): $r = 0.11$; $P = 0.358$
- FCE vs. a* (redness): $r = -0.09$; $P = 0.411$
- FCE vs. b* (yellowness): $r = -0.14$; $P = 0.279$

This suggests that shell pigmentation intensity or hue does not appear to predict metabolic efficiency in egg production.

3.4 Summary of Findings

In summary, while minor numerical differences were observed in feed intake, egg mass, and FCE across eggshell color groups, these variations were not statistically significant. Brown-shell hens showed a tendency toward slightly better feed conversion, but the effect size was small and unlikely to be biologically meaningful. Furthermore, no correlation was found between continuous shell color metrics and FCE, indicating that eggshell pigmentation does not reliably predict feed efficiency under standardized conditions.

4. Discussion

The current study examined the potential relationship between feed conversion efficiency (FCE) in laying hens and eggshell color, an apparent phenotypic feature. The brown shell group showed marginally higher FCE than the white and blue-green groups, although the differences were not statistically significant. Similarly, there was no discernible relationship between FCE and instrumental eggshell color values (L*, a*, and b*). These results imply that when birds are kept in standardized environmental and nutritional settings, eggshell coloring has no discernible impact on feed efficiency.

Consumer preference, shell quality, and internal egg characteristics (Sam) are the main topics in the literature currently available on eggshell color, with little focus on more general performance indicators, such as FCE (Q. Wang et al., 2025). Our results

support this discrepancy and the idea that, although genetically determined and breed-specific, shell color is not a reliable indicator of metabolic efficiency or the conversion of nutrients into egg masses (Ryabova et al., 2025). Therefore, given the available data, it does not seem justified to prioritize eggshell color as a selection criterion for feed efficiency in breeding operations.

The physiological mechanisms controlling feed metabolism and shell coloring function independently could be one reason for this lack of a relationship. Eggshell color is not directly related to energy or protein metabolism; rather, it is largely a consequence of pigment deposition (protoporphyrin IX and biliverdin) during shell formation in the uterus (Kohoutová). Conversely, FCE is a multifaceted characteristic affected by gut health, hormone regulation, reproductive efficiency, and nutrient digestibility (Gao et al., 2025). Although both qualities may be genetically controlled, distinct regulatory pathways may influence their manifestation. Consequently, rather than a genuine physiological connection with shell color, the observed small numerical trends in FCE are more likely to be explained by random biological variation. The objective colorimetric measurement of eggshell pigmentation and the application of uniform housing, feeding, and care procedures for all treatment groups are the two strengths of this study. However, certain restrictions should be considered. Even though the sample size was adequate to identify moderate effect sizes, it might not have been large enough to identify minute variations in FCE between groups. Furthermore, all hens were kept on a single diet and assessed over a brief time frame; longer-term research involving various dietary plans or stressors could help elucidate whether shell color affects efficiency in a context-dependent manner. The possibility of indirect correlations may be further clarified by future studies that use genetic markers for both shell coloration and feed utilization parameters.

5. Conclusion

In this study, laying hens under standardized management settings were used to assess the possible correlation between eggshell color and feed conversion efficiency (FCE). Although there were slight numerical variations in feed intake, egg mass, and FCE between the hens with white, brown, and blue-green shells, these variations were not statistically significant. Additionally, no link between eggshell pigmentation and FCE was found using experimental colorimetric analysis, indicating that the pigmentation hue or intensity is not a valid measure of metabolic efficiency. According to these results, eggshell color is not a reliable indicator of feed efficiency and should not be applied as a criterion for performance trait selection in layer breeding or management initiatives. It could be helpful to conduct long-term feeding studies and additional genetic profiling research to validate these findings in various production settings.

6. Author Contribution

All authors contributed equally

7. Funding

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