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Effect of Dietary Supplementation of Marigold (*Tagetes erecta*) Petal Powder on Yolk Pigmentation, Feed Efficiency and Cost Economics in Desi Layers

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ABSTRACT

The experiment was carried out from January to June, 2023 at the Poultry Instructional and Demonstration Unit (PIDU), College of Veterinary Science and Animal Husbandry, Anjora, Durg, Chhattisgarh, India to evaluate the effect of dietary supplementation of marigold (*Tagetes erecta*) petal powder (MPP) on yolk pigmentation, feed intake, body weight gain, feed conversion ratio (FCR), and cost economics in desi layer birds. Thirty-six 30-week-old desi layers were randomly allocated into three dietary treatments: control (T_0), 2% MPP (T_1), and 4% MPP (T_2), each with three replicates of four birds, for six weeks. Feed intake, body weight gain, FCR, yolk colour (Roche Yolk Colour Fan), and economic parameters were recorded. Results indicated that MPP supplementation had significantly improved yolk pigmentation and FCR. Birds in the 2% MPP group had exhibited optimal performance with higher egg production, improved feed efficiency, and profitability compared to control and 4% MPP groups. Economic analysis revealed that despite slightly higher feed costs, MPP inclusion had enhanced gross returns and benefit-cost ratio, particularly in the 2% group. These findings confirmed that marigold petals, rich in lutein and zeaxanthin, had served as effective natural pigments and functional feed additives. The study concluded that dietary inclusion of marigold petal powder at 2% had been a cost-effective natural alternative to synthetic pigments for enhancing yolk colour, feed efficiency, and profitability in desi layers under semi-intensive production systems.

KEYWORDS: Marigold petal powder, yolk pigmentation, desi layers

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

India's poultry sector is growing at a much faster pace than traditional agriculture. While crop production increases by about 1.5–2% annually, broiler and egg production rise by around 5–6% each year (Sharma et al., 2024). Consequently, India has become the world's third-largest producer of eggs and the eighth-largest producer of broilers (Sharma et al., 2024). Poultry farming is contributing significantly to food security, rural employment, women's empowerment and income generation (Kumar et al., 2022; Goud et al., 2026). Eggs had been recognized as affordable sources of high-quality animal protein, and India had ranked third globally in egg production. Eggs are a highly nutritious and versatile food, providing high-quality protein with excellent bioavailability (over 80%). They are also rich in unsaturated fatty acids such as oleic acid, along with iron, phosphorus, essential trace minerals, and vitamins A, E, K, and the B-complex group, particularly vitamin B (Chauhan and Sreeja, 2025). Consumer preference for eggs had been influenced not only by nutritional value but also by aesthetic traits such as yolk colour, which was perceived as a health and quality component of the product (RehaultGodbert et al., 2019; Zurak et al., 2022). In traditional and semi-intensive markets, deeper yellow yolks were often associated with superior nutrition and higher market value (Asare et al., 2024, Matache et al., 2024a).Conventionally, yolk pigmentation had been enhanced using synthetic pigments such as canthaxanthin and apoester. While effective, these additives had raised concerns regarding cost, chemical residues, and consumer acceptance (Breithaupt, 2007). Farmers typically spent 8–10% of feed cost on pigmentation alone, directly impacting profitability (Diaz et al., 2012). In response, natural alternatives have gained attention for their safety, sustainability, and cost-effectiveness. Marigold (*Tagetes erecta*) petals had been particularly rich in xanthophylls, especially lutein and zeaxanthin, which imparted yellow to orange-red pigmentation in egg yolks. Recent studies have confirmed the pigmenting potential of marigold supplementation. Wei et al. (2023) had shown that different xanthophyll fractions extracted from marigolds significantly improved pigmentation and carcass traits in chickens. Beyond pigmentation, natural pigments such as lutein and zeaxanthin have been associated with functional benefits. Lutein helps to reduce systemic inflammation in growing chicks, and our earlier studies indicate that it modulates immune responses in hens and broilers, primarily targeting the jejunum (Wang et al., 2016, 2022; Gao et al, 2016; Jin et al., 2025). Consumer studies had confirmed that deeper yolk colour increased willingness to pay, thereby improving profitability for farmers (Asare et al., 2024). Economic viability had remained a critical consideration. Although marigold inclusion had slightly increased feed cost, improved egg quality and market acceptance had compensated for the expense. Global market analysts had projected steady growth in demand for natural pigments in poultry feed, with marigold extract recognized as a premium additive. Comparative farm studies have further shown that supplementing natural pigments can enhance overall farm productivity and efficiency, particularly under semi-intensive production systems where both controlled feeding and natural foraging are practiced (Chaves et al., 2022). As a result, this improvement in performance translates into greater economic returns and increased profitability for farmers operating under such conditions. Therefore, the present investigation was undertaken to evaluate the effect of dietary supplementation of marigold petal powder (MPP) at two inclusion levels (2% and 4%) on yolk pigmentation, feed intake, body weight gain, feed conversion ratio, and cost economics in desi layer birds. This study aimed to provide scientific evidence for the use of marigold petals as a natural, cost-effective alternative to synthetic pigments, aligning with the growing demand for sustainable poultry production practices.

2. MATERIALS AND METHODS

2.1. Location of study area

The experiment was conducted at the Poultry Instructional and Demonstration Unit (PIDU), College of Veterinary Science and Animal Husbandry, Anjora, Durg, Chhattisgarh, India, for six months. The trial lasted for six weeks under uniform management conditions. All experimental procedures were carried out following standard poultry management practices, and the birds were maintained under controlled housing, ventilation, and lighting schedules. Clean drinking water and feed were provided ad libitum throughout the study.

2.2. Experimental birds and housing

A total of thirty-six healthy desi layer birds, aged 30 weeks, were selected for the study. Birds were uniform in body weight and health status at the start of the experiment. They were housed in individual cages under standard management practices, with adequate ventilation, controlled temperature, and a 16-hour photoperiod. Clean drinking water and feed were provided ad libitum throughout the experimental period. All birds were vaccinated and dewormed as per standard protocols before the trial.

2.3. Experimental design and dietary treatments

The birds were randomly divided into three dietary treatment groups, each comprising three replicates of four birds (n=12 birds per group):

- T_0 (Control): Basal diet without marigold supplementation
- T_1 (2% MPP): Basal diet supplemented with 2% marigold

petal powder

• T_2 (4% MPP): Basal diet supplemented with 4% marigold petal powder

The marigold petals were shade-dried, ground into fine powder, and incorporated into the basal diet at the specified inclusion levels. The basal diet was formulated to meet the nutrient requirements of laying hens as per ICAR guidelines. The proximate composition of the marigold petal powder was analyzed prior to inclusion using standard procedures. Statistical analysis was performed using GraphPad Prism software (GraphPad Software Inc., 2021), and treatment means were compared using Duncan's Multiple Range Test (Snedecor and Cochran, 1994).

2.4. Feed intake and body weight measurement

Feed intake was recorded daily by subtracting the leftover feed from the total feed offered to each replicate. Weekly feed intake was calculated by summing daily consumption over seven days and expressed as grams per bird per week.

The body weight of individual birds was recorded at the beginning of the experiment and at weekly intervals using a digital weighing balance with a precision of ±1 g. Weighing was done in the morning before feeding to avoid gut fill variation. Weekly body weight gain was calculated by subtracting the previous week's average weight from the current week's average for each replicate.

The feed conversion ratio (FCR**)** was calculated weekly using the formula:

FCR =Average feed intake per bird (g)/Average body weight gain per bird (g)

This served as an indicator of feed efficiency across treatment groups.

2.5. Yolk pigmentation assessment

Eggs were collected daily from each replicate. Six eggs per replicate were randomly selected each week for yolk color evaluation. Yolk pigmentation was assessed using the Roche Yolk Color Fan (RYCF**),** which consists of 15 standardized color categories ranging from pale yellow (score 1) to deep orange (score 15). Yolk samples were placed on a white background under natural daylight, and scores were recorded by a trained observer. The mean yolk color score for each replicate was used for statistical analysis.

2.6. Economic analysis

An economic evaluation was performed to assess the cost-effectiveness of marigold petal powder supplementation. The following parameters were calculated:

• Feed cost per kg of diet, based on prevailing market prices of feed ingredients and marigold petals

• Feed cost per dozen eggs, calculated by dividing total feed cost by the number of eggs produced per replicate

• Net return per bird, derived from the difference between income from egg sales and total feed cost

• Benefit-cost ratio (BCR), calculated as:

BCR=Gross return (₹)÷Total feed cost (₹)

This analysis provided insight into the economic viability of MPP inclusion at different levels.

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2.7. Statistical analysis

All data were analyzed using GraphPad Prism version 9.0.0 (GraphPad Software Inc., San Diego, CA, USA). Results were expressed as Mean ± Standard Error (SE). One-way analysis of variance (ANOVA) was performed to determine significance among treatment means. Duncan's multiple range test (DMRT) was applied for pairwise comparison, where significant differences were observed. A probability level of $p<0.05$ was considered statistically significant.

3. RESULTS AND DISCUSSION

3.1. Feed intake and body weight gain

Weekly feed intake and body weight gain of desi layers under different dietary treatments are presented in Tables 1 and 2. Birds in all groups consumed feed normally throughout the six-week trial, with no signs of feed refusal or palatability issues in marigold-supplemented groups. Feed intake was numerically higher in the control group (T_0) during the initial weeks, while birds in the 2% MPP group (T_1) showed slightly reduced intake but improved weight gain. The 4% MPP group (T_2) had comparable intake to the control but exhibited marginally lower weight gain in later weeks. Statistical analysis revealed significantly higher body weight gain ($p<0.05$) in T_1 during weeks 3 to 6 compared to T_0 and T_2.

Table 1: Weekly feed intake (g bird^{-1}) in desi layers supplemented with marigold petal powder

Week	T_0 (Control)	T_1 (2% MPP)	T_2 (4% MPP)
1	118.4±2.1	116.2±1.8	117.5±2.0
2	122.6±2.3	120.1±2.0	121.3±2.2
3	125.3±2.5	123.0±2.1	124.2±2.4
4	127.8±2.6	125.5±2.3	126.7±2.5
5	130.2±2.7	127.6±2.4	129.0±2.6
6	132.5±2.8	129.8±2.5	131.1±2.7
Total	756.8±14.0	742.2±12.9	750.8±13.8

Values are Mean±SE; no significant differences observed ($p>0.05$)

Table 2: Weekly body weight gain (g bird^{-1}) in desi layers supplemented with marigold petal powder

Week	T_0 (Control)	T_1 (2% MPP)	T_2 (4% MPP)
1	45.2±1.5	46.8±1.6	45.9±1.5
2	48.6±1.6	50.2±1.7	49.1±1.6
3	52.3±1.7	55.6±1.8	53.4±1.7
4	54.1±1.8	58.3±1.9	55.2±1.8
5	56.0±1.9	60.1±2.0	57.0±1.9
6	57.4±2.0	61.5±2.1	58.6±2.0
Total	313.6±10.5	332.5±11.1	318.2±10.7

Values are Mean±SE; T_1 significantly higher than T_0 and T_2 from week 3 onward (p<0.05)

These findings suggested that moderate inclusion of marigold petal powder enhanced nutrient utilization and growth performance. Similar improvements in body weight gain were reported in quails supplemented with marigold flower extract. Wei et al. (2023) further demonstrated that xanthophyll fractions from marigold improved carcass traits and pigmentation in chickens.

3.2. *Feed conversion ratio (FCR)*

Weekly FCR values are illustrated in Figure 1. Birds in the T_1 group (2% MPP) consistently showed better FCR compared to control and T_2, particularly during weeks 4 to 6. The lowest FCR was recorded in week 6 for T_1 (1.98), indicating efficient feed utilization. Improved FCR in MPP-supplemented groups could be attributed to the antioxidant properties of lutein and zeaxanthin, which enhanced gut health and nutrient absorption. Similar observations were reported by Udchachon et al. (2021).

- T_1 (2% MPP) consistently shows the lowest FCR, indicating superior feed efficiency.
- T_0 (Control) and T_2 (4% MPP) follow similar patterns, with T_2 slightly better than control in later weeks.

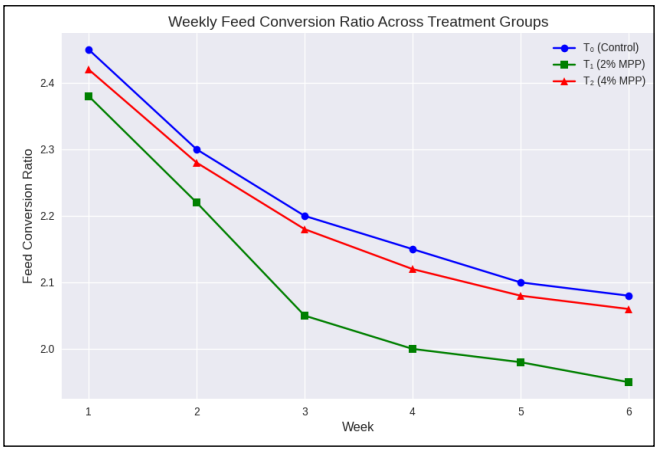

Figure 1: Weekly feed conversion ratio across treatment groups

3.3. *Yolk pigmentation*

The effect of marigold petal powder supplementation on yolk pigmentation is presented in Table 3. A significant increase (p<0.01) in yolk colour scores was observed in both MPP-supplemented groups compared to the control. The highest mean score (9.2) was recorded in T_2 (4% MPP) during week 6, while T_1 (2% MPP) maintained a consistent score of 8.5 from week 4 onwards. These results confirmed the pigmenting potential of marigold petals, which contain high concentrations of xanthophylls, particularly lutein and zeaxanthin.

Table 3: Weekly yolk colour scores (Roche Yolk Colour Fan) in desi layers supplemented with marigold petal powder

Week	T_0 (Control)	T_1 (2% MPP)	T_2 (4% MPP)
1	4.2±0.3	6.8±0.4	7.2±0.4
2	4.5±0.3	7.1±0.4	7.5±0.4
3	4.7±0.3	7.4±0.4	7.8±0.4
4	5.0±0.3	8.2±0.4	8.6±0.4
5	5.2±0.3	8.4±0.4	8.9±0.4
6	5.3±0.3	8.5±0.4	9.2±0.4
Total	4.82±0.3	7.73±0.4	8.20±0.4

Values are Mean±SE; yolk colour significantly higher in T_1 and T_2 compared to control (p<0.01)

Similar findings were reported by Mahanta et al. (2022), Hasin et al. (2006) and Rowghani et al. (2006), who demonstrated significant improvement in yolk colour with marigold inclusion. More recently, Wei et al. (2023) confirmed that marigold xanthophyll fractions improved pigmentation in chickens. Consumer preference studies also indicated that deeper yolk colour increased market acceptance and willingness to pay (Asare et al., 2024).

3.4. *Economic analysis*

Economic parameters of desi layers under different dietary treatments are summarized in Table 4. Feed cost per kilogram increased with higher marigold inclusion (₹ 24.00 in T_0, ₹ 26.00 in T_1, and ₹ 27.00 in T_2). However, egg production was highest in T_1 (13 eggs bird^{-1}), followed by T_2 (12.4 eggs bird^{-1}) and T_0 (12 eggs bird^{-1}). Feed consumed per egg was lowest in T_1 (283.84 g), indicating superior feed efficiency.

Despite slightly higher feed costs, MPP-supplemented groups yielded greater returns due to enhanced yolk pigmentation and higher egg prices. Gross returns per bird were ₹ 130.00 in T_1 and ₹ 136.40 in T_2, compared to ₹ 96.00 in the control. Profit percentage was highest in T_2 (27.55%), followed closely by T_1 (26.20%), while control showed only 8.25%. The benefit cost ratio (BCR) was highest in T_2 (1.38), but T_1 offered the most balanced outcome in terms

Table 4: Economic parameters in desi layers supplemented with marigold petal powder

Parameter	T_0 (Control)	T_1 (2% MPP)	T_2 (4% MPP)
Feed cost kg^{-1} (₹)	24.00	26.00	27.00
Total feed intake bird^{-1} (kg)	3.67	3.69	3.66
Egg production bird^{-1} (number)	12.00	13.00	12.40
Feed consumed egg^{-1} (g)	305.83	283.84	295.16
Cost of production egg^{-1} (₹)	7.34	7.38	7.97
Egg selling price (₹ egg^{-1})	8.00	10.00	11.00
Gross returns bird^{-1} (₹)	96.00	130.00	136.40
Profit percentage (%)	8.25	26.20	27.55
Benefit-cost ratio (BCR)	1.08	1.36	1.38

The T_1 group showed an optimal balance between feed efficiency, profitability, and market acceptance

of feed efficiency, profitability, and consumer acceptance.

These results were consistent with Diaz et al. (2012) and Nys (2000), who emphasized the economic importance of pigmentation in poultry production. More recent studies also confirmed the profitability of natural pigment supplementation. Asare et al. (2024) reported that deeper yolk colour significantly increased consumer willingness to pay in local markets. Consumers often link deeper-colored egg yolks with superior nutritional value and added health benefits, viewing them as a sign of healthy hens raised on a well-balanced, nutrient-rich diet (Ortiz et al., 2022, Matache et al., 2024b). Wei et al. (2023) highlighted that marigold xanthophyll fractions improved carcass traits and pigmentation, indirectly enhancing economic returns. A study also showed that incorporating natural pigments from marigold and paprika extracts, which possess strong antioxidant properties, into the diets of laying hens enhanced egg quality after 28 days of storage under both refrigerated (4°C) and room temperature (20°C) conditions, thereby extending shelf life, reducing post-production losses, and ultimately improving the economic returns for farmers (Matache et al., 2024a).

4. CONCLUSION

The dietary supplementation of marigold petal powder (MPP) in desi layer diets significantly enhanced yolk pigmentation and improved feed conversion efficiency without adversely affecting feed intake or body weight gain. Among the treatment groups, the 2% MPP inclusion level (T_1) yielded optimal results in terms of yolk colour intensity, growth performance, and economic return. Thus, marigold petals served as a cost-effective natural alternative to synthetic pigments under semi-intensive production systems.

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