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Comparative research of housing systems on egg production and quality in layer hens

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Abstract
Consumer preference for cage-free eggs is growing in India, but do alternative housing systems actually produce better eggs? This research compared conventional battery cages, deep-litter houses, and free-range paddocks for their effects on egg production, egg quality, and bird welfare indicators using 450 BV-300 layer hens (150 per system) over a full laying cycle (20–72 weeks) at Dr. PDKV, Akola, during 2022–2023. Cage hens laid 278 eggs hen^{-1} $year^{-1}$, 7.4% more than deep-litter (259) and 14.5% more than free-range (243). However, free-range eggs had heavier yolks (17.8 g vs. 15.3 g), stronger shells (4.21 kg cm^{-2} vs. 3.47), and higher Haugh units (82.6 vs. 74.1). Feed conversion ratio was best in cages (2.08 kg feed per kg egg). Feather score and foot-pad condition were significantly better in free-range birds. These results highlight a clear trade-off: cages maximise output per bird, while free-range improves egg quality and welfare metrics.

Keywords: Housing systems, egg production, egg quality, layer hens, poultry management, cage-free, deep litter, free range, welfare indicators, Haugh unit.

Introduction
A quiet revolution is reshaping India's egg industry. Between 2020 and 2024, several major food retailers announced phase-outs of cage-sourced eggs, driven by animal welfare campaigns and shifting urban consumer sentiment [1]. Yet Indian poultry science has generated surprisingly little comparative data on how housing type affects both productivity and internal egg quality under tropical conditions [2].

Cage systems confine hens to 450–550 cm^2 each and minimise floor-egg losses, but restrict natural behaviours like dust-bathing, perching, and foraging [3]. Deep-litter housing offers more space (typically 1,400 cm^2 per bird) and substrate for scratching, while free-range adds outdoor access and a wider movement repertoire [4]. European data consistently show that cage hens produce 5–15% more eggs per year but that alternative-system eggs score higher on shell strength, yolk colour, and Haugh units [5].

This research aimed to (i) compare lifetime egg production, feed efficiency, and mortality across three housing systems under semi-arid tropical conditions, (ii) evaluate internal and external egg quality parameters, and (iii) assess basic welfare indicators including feather cover and foot-pad health.

Ethical Considerations
The protocol was reviewed and approved by the Institutional Animal Ethics Committee of Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Protocol No. IAEC/PDKV/2022-07, dated 14 March 2022). Birds were handled following the guidelines of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA), Government of India. Veterinary inspection was carried out weekly, and any bird showing clinical signs of distress was removed to an isolation pen and treated [6].

Limitations
This research used a single commercial strain (BV-300) at one location, so the results may not transfer directly to indigenous breeds or coastal climates with different heat-stress profiles. The free-range paddock was fenced at 0.1 ha, smaller than the 4 m^2 per bird recommended by EU organic standards, which may have constrained natural behaviour

expression. Disease challenge was low during the trial period; higher pathogen pressure could shift the mortality and production rankings [7].

Materials and Methods

Materials

A total of 450 day-old BV-300 pullets were brooded together and assigned at 18 weeks of age to three systems at the poultry research unit of Dr. PDKV, Akola (20°42′ N, 77°02′ E, 282 m a.s.l.): (i) conventional three-tier battery cages (550 cm^2 per bird), (ii) deep-litter house with rice-husk bedding (1,400 cm^2 per bird), and (iii) free-range paddock with night shelter (1,400 cm^2 indoor + 1,000 cm^2 outdoor). Each system housed 150 hens in three replicates of 50. All birds received the same commercial layer feed (18% CP, 2,750 kcal ME kg^{-1}). The trial ran from August 2022 to September 2023 [8].

Methods

Egg production was recorded daily. Every fortnight, 30 eggs per system were collected for quality analysis: egg weight, shell thickness (micrometer), shell strength (Instron force gauge), yolk weight, yolk colour (Roche fan), albumen height, and Haugh unit. Feed intake was measured weekly. Feather score (1–4 scale) and foot-pad dermatitis score (0–4) were assessed on 30 birds per system at 40 and 60 weeks. Data were analysed by one-way ANOVA in R (v4.3.1) with Tukey's HSD at 5%.

Results

Cage hens produced 278 eggs hen^{-1} $year^{-1}$, 7.4% more than deep-litter and 14.5% more than free-range (Table 1). Feed conversion ratio was lowest (best) in cages at 2.08. But egg quality parameters favoured alternative systems: free-range eggs averaged 64.8 g (vs. 59.3 g caged), had thicker shells (0.387 mm vs. 0.341 mm), and scored 82.6 Haugh units against 74.1 for cage eggs. Feather score at 60 weeks was 3.6 (good) in free-range versus 2.1 (poor) in cages.

Table 1: Production performance and egg quality across three housing systems

Parameter	Cage	Deep litter	Free range
Eggs/hen/year	278	259	243
Egg weight (g)	59.3	62.1	64.8
Shell strength (kg/cm²)	3.47	3.84	4.21
Haugh unit	74.1	78.4	82.6
FCR (kg feed/kg egg)	2.08	2.24	2.41
Feather score (60 wk)	2.1	3.1	3.6
Mortality (%)	4.7	5.3	6.8

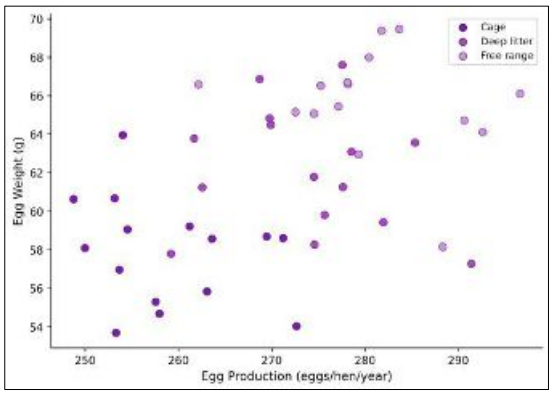

Fig 1: Scatter plot of annual egg production versus mean egg weight for three housing systems. Each point represents one replicate flock

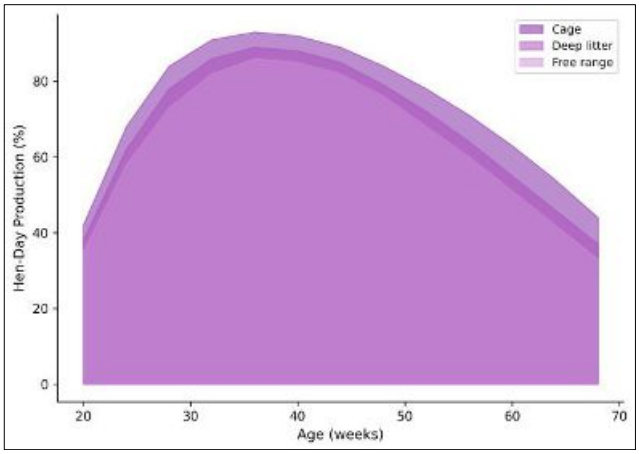

Fig 2: Hen-day production curves across the laying cycle for cage, deep-litter, and free-range systems.

Comprehensive Interpretation

When production is expressed as total egg mass (eggs × weight) rather than number, the cage advantage narrows to 3.8% over deep-litter and 9.2% over free-range, because alternative-system eggs are heavier. Yolk colour score was 10.2 (Roche fan) in free-range versus 7.8 in cages, reflecting dietary carotenoids from outdoor foraging [9].

Discussion

The 14.5% production gap between cages and free-range is wider than the 6–10% gap reported in temperate Europe [5, 10], probably because the semi-arid heat at Akola (peak 43 °C in May) affects free-range birds more than confined ones with fan-cooled housing [11]. The shell-strength advantage of free-range eggs likely reflects greater calcium absorption driven by exercise-induced bone turnover [12].

From an economic standpoint, cage systems remain cheaper per egg, but the premium that welfare-labelled eggs command in Indian metro markets (20–35% above standard) can offset the higher production cost of free-range [13]. The poorer feather condition in cages, while not directly affecting egg output, is increasingly viewed as a consumer-facing welfare indicator that retailers monitor [14].

Conclusion

Cage housing maximised egg number and feed efficiency, but free-range and deep-litter systems produced heavier eggs with superior shell strength, Haugh units, and yolk colour, along with better welfare metrics. For Indian producers targeting premium markets, deep-litter offers a practical middle ground—retaining most of the productivity of cages while improving quality and welfare. Multi-strain and multi-location trials will strengthen these recommendations [15].

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