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Performance Assessment of Naked Neck Chickens under Different Production Systems

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Abstract: The aim of this study was to compare the performance of Naked Neck chickens in three production systems: free-range, aviary, and open-sided house. A total of 540 Naked Neck chickens (25 weeks of age; 1400 ± 20 g body weight) were equally divided into three treatment groups, with six replicates of 30 birds each, following a Completely Randomized Design. In each production system, 60 birds per house were placed, with two replicates per house comprising 30 birds each. A litter depth of 2–3 inches (a mixture of rice husk and wheat straw) was spread on the floor as bedding material. Similarly, 30 birds per aviary were placed in each aviary unit. For the free-range system, a total of three houses were used, each with two replicates containing 30 birds per replicate. The effects of different production systems were evaluated on the birds' productive performance, egg characteristics, and hatching traits. Egg production and egg quality (both internal and external) were observed to be superior in the open-sided house production system compared to the others. However, in terms of hatching traits, the hatchability percentage was significantly higher in birds reared under the free-range production system, followed by the aviary and open-sided house systems. In conclusion, the bird under consideration, the Naked Neck, performed well in all three production systems; however, overall results, except for hatching traits, were better in the open-sided production system.

Keywords: Naked Neck; production systems; productive performance; egg quality; hatching traits

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1. Introduction

Backyard poultry farming is considered a viable alternative to commercial production systems, as it offers higher economic returns with a relatively low initial investment. It serves as an affordable source of protein for the most vulnerable communities. In Pakistan, the estimated population of domestic poultry is 95.5 million birds [1]. Furthermore, promoting backyard poultry production systems can enable millions of rural families to sustain their livelihoods over time.

In Pakistan, indigenous breeds such as Naked Neck, Fayoumi, Aseel, and Desi are generally regarded as rustic chicken breeds, commonly reared as courtyard poultry [2]. These breeds are domestically raised for both meat and egg production in rural areas [3]. The Naked Neck breed is naturally devoid of feathers on its neck and vent. It is a dual-purpose breed known for its heat tolerance and disease resistance and is considered well-adapted to challenging environments [4]. Although primarily recommended for backyard poultry production systems, the Naked Neck can also adapt well to other systems, such as open-sided houses and aviaries. The average egg production potential of Naked Neck chickens is approximately 135–138 eggs per year, with average body weights of about 1.1 kg for females and 1.5 kg for males.

Domestic poultry plays an important role in providing affordable sources of protein and is consistently promoted through local farming practices in developing countries. Numerous studies have been conducted to determine the most suitable production systems for poultry rearing. Over the years, the practice of rearing chickens has become increasingly common not only in rural areas but also in urban settings across the United Kingdom and other developed countries [5–7]. According to Mandal et al. [8], backyard poultry farming has always contributed significantly to the production of healthy birds. The sale of birds and eggs from backyard systems often commands higher prices compared to commercially produced broilers and eggs, making backyard poultry economically advantageous [9].

Furthermore, backyard poultry farming has proven to be a climate-resilient production system due to the birds' inherent disease resistance and ability to thrive under extreme environmental conditions [10]. Various production systems are employed to rear poultry under challenging environments, including free-range systems, open-house systems, environmentally controlled systems, and aviaries. However, housing birds in cages within these systems restricts their ability to express natural behaviors such as perching, dust bathing, and nesting. Recognizing this welfare concern, the European Union imposed a temporary ban on conventional cages in 2012, which subsequently led to the promotion of alternative production systems.

In Pakistan, backyard poultry production is gaining popularity in both rural and urban areas. The prevailing economic conditions necessitate the promotion of low-investment enterprises to support food security and rural livelihoods. In this context, the present study aimed to evaluate the productive and growth performance of a dual-purpose chicken breed under different production systems.

2. Materials and Methods

The present study was conducted at the Avian Research and Training Centre, Department of Poultry Production, University of Veterinary and Animal Sciences (UVAS), Ravi Campus, Pattoki. The study site is located at 73°50′60″ E and 31°1′0″ N, at an altitude of 186 meters, and is characterized by a semi-arid climate with hot and humid summers.

2.1. Experimental Design and Study Groups

A total of 540 Naked Neck chickens (25 weeks of age; 1400 ± 20 g body weight) were randomly assigned to three experimental groups, following a Completely Randomized Design, with six replicates of 30 birds each. The groups consisted of three housing systems: open-sided housing, aviary, and free-range.

The **open-sided housing system** confined birds within a four-walled structure without outdoor access. The side walls were partially open, equipped with mesh and adjustable curtains to allow natural ventilation while preventing birds from escaping. Each shed measured 20 × 20 × 12 feet and was equipped with round feeders and nipple drinkers. A total of 60 birds were housed in this system, divided into two replicates of 30 birds each. The floor was covered with 2–3 inches of bedding material, consisting of a mixture of rice husk and chopped wheat straw. Ceiling fans were installed to enhance ventilation, and LED bulbs provided lighting. Although birds did not have outdoor access, a nesting system with multiple nests was provided in each replicate (Table 1).

The **aviary system** offered birds access to both enclosed and open areas. Each aviary housed 30 birds and was equipped with ventilation fans in the enclosed section, along with open windows allowing outdoor access. The floor was similarly covered with 2–3 inches of bedding made from wheat straw and rice husk. A nesting system was available, along with round feeders and nipple drinkers for feeding and drinking (Table 1).

In the **free-range system**, birds were allowed full freedom of movement, including unrestricted outdoor access. A sheltered area equipped with nests was provided, and perches were installed in the outdoor free-range space. This system consisted of three houses, with two replicates per house, accommodating 30 birds per replicate (Table 1).

Further details of the production systems, including stocking density, dimensions of the open area, sex ratio, and other parameters, are presented in Table 1.

Figure 1. Experimental facility depicting the three production systems: (A) open-sided housing, (B) aviary housing system, and (C) free-range system.

Table 1. Description of different housing systems.

Specifications	Open-sided	Aviary	Free range
Dimensions, cm Length × width × height			
Covered area	609.6 × 609.6 × 365.76	304.8 × 304.8 × 304.8	548.64 × 304.8 × 243.84
Open area		579.12 × 304.8 × 274.32	1249.68 × 548.64
Production system + Replicates + Birds (Each replicate)	3 × 06 × 30	3 × 06 × 30	3 × 06 × 30
Stocking density	30 birds/replicate	30 birds/replicate	30 birds/ partition
Sex ratio (male: female)	5:25 (each replicate)	5:25 (each replicate)	5:25 (each partition)
Space per bird (cm^2)	6193.54	1548.38 (open area) 2941.93 (closed area)	2787.09 11427.07 (each partition)
Litter	Rice husk/wheat straw	Rice husk/wheat straw	
Nesting			
Number of nests	5	5	5
Nesting dimension (cm)	25.4 × 22.86 × 22.86	25.4 × 22.86 × 22.86	25.4 × 22.86 × 22.86
Perches			
Number of perches	--	3	6
Material	--	Wooden	Wooden
Shape	--	Round	Round
Diameter (cm)	--	2.5	2.5
Length (cm)	--	91.44	152.4
Height from floor (cm)	--	45.72 - 60.96	45.72 - 60.96
Perching space/bird (cm)	--	11.43	38.1

2.2. Productive Performance

The following parameters were studied to evaluate productive performance (from 25 to 48 weeks of age) and egg size (ranging between 45 and 55 grams):

Body Weight (g): The body weight of each bird was recorded at the start of the experiment and subsequently measured on a weekly basis using an electronic weighing balance with an accuracy of up to 5 grams. Weekly average body weight, uniformity, and range were calculated.

A feed allowance of 100 grams per bird was offered daily at 6:00 AM in feeders provided within each production system. Daily feed intake was determined by subtracting the refused feed from the offered feed. Weekly feed intake was calculated by summing the daily feed intake over seven consecutive days. Cumulative feed intake was obtained by adding the current week's intake to the cumulative intake from previous weeks.

Egg production was monitored on a daily basis. Eggs were collected twice per day—once in the morning and once in the evening—from each production system. Each egg was labeled with the corresponding production system and collection date for accurate record-keeping. The weight of each egg was measured individually using an electronic balance with a precision of 0.1 grams. Average egg mass was calculated by multiplying the hen-day egg production percentage by the average egg weight (in grams):

$$\text{Egg Mass (g)} = \text{Production Percentage} \times \text{Average Egg Weight (g)}$$

2.3 Egg Geometry

Egg geometry measurements included shape index, surface area (cm²), and volume (cm³). The width and length of each egg were measured using a Vernier caliper with a least count of 0.1 mm. The egg shape index was calculated using the following formula [11]:

$$\text{Egg Shape Index (\%)} = (\text{Egg Width} / \text{Egg Length}) \times 100$$

The surface area and volume of the eggs were calculated using the formulas described by Sreenivasiah [12]:

$$\text{Surface Area (cm}^2\text{)} = k \times W^{0.67}$$

$$\text{Volume (cm}^3\text{)} = 0.913 \times W$$

where k is 4.558 and W is the egg weight (g).

2.4. Egg Quality

Eggs collected from each production system were selected for the evaluation of external and internal quality parameters.

Shell Weight (g): The eggshell was carefully cleaned and weighed using an electronic balance with an accuracy of 0.1 g.

Shell Thickness (mm): Eggshell thickness was measured at three different points (broad end, equator, and narrow end) using a micrometer screw gauge, and the average value was recorded.

Shell Breaking Strength (N): The shell breaking strength of eggs was measured using an Egg Force Reader (Orka Food Technology Ltd., Herzliya, Israel).

Albumen Height (mm): The height of the albumen was measured using Vernier calipers with a least count of 0.1 mm. This measurement was further used for the calculation of the Haugh unit.

Albumen Weight (g): The albumen of each egg was separated and weighed individually using an electronic balance with a precision of 0.1 g.

Haugh Unit Score: The Haugh unit (HU) was calculated to evaluate internal egg quality, using albumen height and egg weight, as per the method of Haugh [13]. The formula used was:

$$\text{Haugh Unit} = 100 \times \log_{10} (H + 7.57 - 1.7 \times W^{0.37})$$

Where H is the albumen height (mm) and W is the egg weight (g).

Yolk Height and Width (mm): The height and diameter of the yolk were recorded at three distinct locations using Vernier calipers, and the mean values obtained were utilized to determine the yolk index.

Yolk Index: The quality of the yolk was evaluated by computing the yolk index, which was derived using the following formula:

$$\text{Yolk Index} = (\text{Yolk Height} / \text{Yolk Width}) \times 100$$

Yolk Weight (g): The yolk was carefully separated and weighed individually using an electronic balance with a precision of 0.1 g.

Eggshell Pore Number: The number of pores on the eggshell surface was estimated using the equation proposed by Rahn and Paganelli [14]:

$$\text{Pore Number (N)} = 304 \times W^{0.767}$$

Where W is the egg weight (g).

2.5 Hatching Traits

At the final stage of the experiment, the eggs were set in an incubator, and hatching traits were recorded after 21 days of incubation.

Infertile Eggs (%): Infertile eggs were identified through breakout analysis by examining the unhatched eggs, which appeared clear upon candling at the time of hatch. The proportion of infertile eggs was determined using the formula below:

$$\text{Infertile eggs (\%)} = [\text{Number of infertile (clear) eggs} / \text{Number of eggs set}] \times 100$$

Hatchability (%): Hatchability was determined using the following formula:

Hatchability (%) = Number of chicks hatched / Number of eggs set × 100

Hatchability of Fertile Eggs (%): Hatchability of fertile eggs was calculated by first subtracting the number of infertile (clear) eggs from the total eggs set. The following formula was applied:

Hatch of fertile (%) = (Number of chicks hatched / Number of fertile eggs) × 100

Fertility (%): Fertility was calculated by subtracting the number of clear eggs from the total number of eggs set. The percentage of fertile eggs was then calculated using the formula:

Fertility (%) = Number of fertile eggs / Number of eggs set × 100

Embryonic Mortality (%): Embryonic mortality was assessed by breakout analysis, and the percentage was calculated using the following formula:

Embryonic mortality (%) = Number of dead embryos Number of eggs set × 100

2.5. Statistical Analysis

Effects of different housing systems on productive performance, egg quality characteristics, and hatching traits were evaluated through one-way ANOVA technique using PROC GLM in SAS software (SAS 9.1, SAS Institute Inc., Cary, NC, USA). For the comparison of significant treatment means Fisher's Least Significant Difference test [15] was applied considering $p \leq 0.05$.

3. Results

3.1. Productive Performance

Significant differences were observed at both the initial (26 weeks) and final (48 weeks) stages of the experiment, where the body weight of both male and female birds was higher in those reared in the open-sided housing system compared to those kept in aviaries. Additionally, the open-sided housing system demonstrated significantly ($p \leq 0.05$) higher performance in terms of egg production, egg number, production percentage, and egg mass. The highest production percentage was recorded in birds reared under the open house system, followed by those in free-range and aviary systems, respectively.

No significant differences were observed among the different housing or production systems regarding livability percentage. Similarly, egg weight did not differ significantly among the housing systems (Table 2).

Table 2. Productive performance of Naked Neck chickens (25–48 weeks) reared under different production systems.

Traits	Age	Aviary	Free-range	Open-sided	SEM	*p*-value
Male body weight (g)	26 weeks	1786.67^{b}	1750.00^{c}	1818.67^{a}	10.25	0.0003
	48 weeks	1961.33^{ab}	1910.00^{b}	2004.33^{a}	15.80	0.0166
Female body weight (g)	26 weeks	1306.67^{ab}	1253.33^{b}	1360.00^{a}	10.25	0.0241
	48 weeks	1601.67^{b}	1518.33^{b}	1701.67^{a}	15.80	0.0079
Egg weight (g)		45.29	45.49	45.50	0.14	0.8404
Egg number		78.10^{b}	84.35^{ab}	91.28^{a}	2.28	0.0271
Production (%)		50.58^{b}	54.64^{ab}	59.14^{a}	1.48	0.0271
Egg mass (kg)		3.28^{b}	3.56^{ab}	3.85^{a}	0.10	0.0207
Livability (%)		90.89	91.12	90.88	0.06	0.2475

$^{a–c}$ within the row, means with different superscripts differ significantly at $p \leq 0.05$.

3.2. Egg Characteristics

Egg morphometric traits, specifically egg length (p = 0.0001) and egg width (p = 0.0006), were significantly higher in eggs produced in the aviary system. The egg width in aviaries was recorded as 46.41 mm, whereas eggs from the free-range system showed a lower value of 45.34 mm. Conversely, egg surface area (p < 0.0001) and egg volume (p < 0.0001) were significantly higher in the open-sided housing system.

Moreover, egg weight was significantly higher (p < 0.0001) in birds reared in the open-sided house. Among the internal egg quality parameters, yolk weight (p = 0.0066), yolk height (p = 0.0015), yolk width (p = 0.0002), Haugh unit (p = 0.0235), and eggshell weight (p < 0.0001) were all significantly higher in eggs obtained from the aviary system. These significant differences in egg morphometric and quality traits were attributed to the variations in housing and production systems (Table 3).

Table 3. Egg characteristics of Naked Neck chickens reared under different production systems.

Traits	Aviary	Free range	Open sided	SEM	*p*-value
Egg length (mm)	63.28^a	61.82^b	60.08^c	0.40	0.0001
Egg width (mm)	46.41^a	45.34^b	43.79^c	0.34	0.0006
Egg shape index	73.34	73.34	72.88	0.14	0.3451
Egg surface area (cm^2)	61.82^b	60.81^b	67.13^a	0.80	<0.0001
Egg volume (cm^3)	44.74^b	43.64^b	50.58^a	0.88	<0.0001
Egg weight (g)	49.00^b	47.80^b	55.40^a	0.96	<0.0001
Yolk weight (g)	22.48^a	21.52^b	21.12^b	0.20	0.0066
Yolk height (mm)	16.59^a	16.21^a	15.61^b	0.13	0.0015
Yolk width (mm)	39.78^a	38.87^a	36.72^b	0.39	0.0002
Yolk index	41.70	41.70	42.53	0.19	0.1126
Albumen height (mm)	7.50	7.32	7.39	0.06	0.5023
Albumen weight (g)	35.64	34.46	34.56	0.26	0.1131
Haugh unit score	89.71^a	89.12^a	87.18^b	0.42	0.0235
Egg shell weight (g)	9.00^a	8.80^b	8.51^c	0.06	<0.0001
Egg shell thickness	0.40	0.39	0.40	0.001	0.2471
Shell breaking strength (N)	44.6	42.8	43.9	0.04	0.1293
Shell pore numbers	6014.53^b	5901.62^b	6608.95^a	89.74	<0.0001

$^{a–c}$ within the row, means with different superscripts differ significantly at $p \le 0.05$.

3.3. Hatching Traits

Regarding hatching traits, fertility (p = 0.0180) and hatchability (p < 0.0001) were significantly higher in the free-range production system compared to the other housing systems. However, no significant differences were observed among the treatment groups in terms of infertile egg percentage and embryonic mortality, both early and late (Table 4). Notably, the percentage of infertile eggs was significantly higher in the open-sided housing system compared to the free-range and aviary systems.

Table 4. Hatching traits of Naked Neck chicken reared under different production systems.

Traits (%)	Aviary	Free-range	Open-sided	SEM	*p*-value
Hatchability	67.83^b	73.06^a	63.40^c	0.97	<0.0001
Fertility	84.19^b	88.24^a	82.58^b	0.87	0.0180

Infertile eggs	15.81^{a}	11.76^{b}	17.42^{a}	0.87	0.0180
Early embryonic mortality (1-18 d)	7.26	7.76	9.53	0.43	0.0692
Late embryonic mortality (19-21 d)	9.10	7.43	9.65	0.48	0.1397

$^{a–c}$ within the row, means differ superscripts differ significantly at $p \leq 0.05$.

4. Discussion

The present study aimed to explore the productive performance, egg quality and hatching traits of naked neck chicken in three different production systems. This was successful as significant results were obtained in terms of productive performance, egg quality and hatching traits. Both male and female body weight was higher in open house production system. The higher body weight in open-sided housing might be associated with the availability of adequate rearing space with sufficient physical activity reinforced the bird in better welfare and more utilization of nutrients in weight gain than aviary system as birds in this system were using more energy in activities instead of weight gain, egg weight and egg number. However, the rearing space and locomotory activity was higher in free range system which leads to the wastage of nutrients in greater physical activities rather than using them in weight gain. Similar findings were observed by another study stated that greater physical activity of birds in enriched cages caused more burning of nutrients leading to more nutrient intake and hence greater weight gain and muscle mass in birds in enriched cages than birds residing in aviaries [14]. However, contrary findings reported better egg and body morphometric traits due to increased locomotory activities in semi-intensive and free-range production system [16].

Birds in open house production system showed better productive performance as compared to birds in aviaries and free-range. Good weight gain was observed in birds in open-sided housing system due to less locomotory activity and adequate space availability with maximum utilization of nutrients. A contrary study reveals that the well-being of domestic fowl plays a significant role in the level of production and birds are known to respond to stress-full environment with reduced egg production [16, 17]. Similar findings observed improved productive performance of Indigenous Aseel chicken reared under confined and semi- intensive production systems [18]. Aernia et al. [19] reported that productive performance of birds was reduced in aviaries and cannibalism and mortality rates were not affected.

Good productive performance leads to good quality eggs. Eggs obtained from birds reared in open-sided housing were greater in weight than eggs obtained from birds reared in aviaries and free-range production system. The reason that egg number, weight and mass were greater in eggs collected from open-sided housing system as compared to aviaries and in the free range, is because birds in open-sided housing were subjected to good nutrient utilization due to improved physical activities like jumping, flying, and dusting. Whereas, in some studies egg weight remained unresponsive to the rearing systems [19]. Meanwhile similar studies reveal that eggs obtained from enriched cages show higher egg weight, surface area, egg volume and Haugh unit score as compared to eggs obtained from aviaries [20]. A contradictory study reveals that eggs obtained from free-range housing indicate large surface area as compared to eggs obtained from caged area [21]. The poultry industry is becoming increasingly concerned with egg quality due to growing consumer awareness [22].

Several studies have shown that egg quality traits differ significantly among chicken genotypes and rearing systems. For example, naked neck birds have been reported to produce eggs with superior characteristics such as greater egg weight, length, shell weight, yolk weight, and yolk height compared to other genotypes [17]. These traits are influenced by a combination of genetic and non-genetic factors, including nutrition, housing system, environmental conditions, and stress exposure.

The rearing system plays a critical role in determining egg quality. Birds raised in free-range environments tend to produce eggs with distinct morphometric and internal quality attributes, as well as enhanced nutritional profiles due to natural foraging behavior [23]. However, hens in aviary or battery cage systems often yield eggs with higher shell breaking strength and shell weight compared to those from free-range or open-sided systems [21]. Moreover, yolk weight and Haugh unit values are often higher in eggs from aviary systems, indicating superior internal quality.

Open-sided housing systems are associated with increased egg size and bird body weight, potentially leading to reduced shell percentage due to the demand for calcium in embryonic development. A previous study suggested that larger eggs require more calcium for skeletal development in chicks, which may result in thinner shells [24]. Additionally, shell percentage has been found to decline with hen age in battery cage systems, while it tends to fluctuate over time in free-range setups [23].

Egg quality is further influenced by diet composition. Specific feeding regimens can improve nutrient deposition in eggs and strengthen shell quality, highlighting the importance of nutritional management in layer production [25].

Hatchability percentage has been reported to be highest in birds reared under free-range production systems, followed by those in aviary and open-house systems. This improvement in hatchability may be attributed to enhanced acquired immunity and access to natural growth factors obtained through foraging in free-range conditions. However, conflicting evidence exists; some studies have shown that birds reared under confinement or semi-intensive systems exhibit higher hatchability rates compared to those raised in free-range environments [18].

Improved fertility and hatchability in free-range systems may result from sound management practices, including adequate nutrition, optimal body weight gain, and increased physical activity, all of which contribute to better reproductive performance. Indeed, research indicates that effective management interventions can significantly enhance the fertility rates of breeding flocks [26].

5. Conclusions

In conclusion, the open-sided housing system demonstrated superior performance in terms of productive parameters and egg geometric traits, while the free-range production system exhibited better hatching traits. These findings suggest that both housing systems can be effectively adopted for backyard poultry production to enhance bird performance. However, for dual-purpose breeds, the open-sided housing system is recommended due to its favorable impact on growth and egg production under controlled conditions.

Furthermore, it is recommended that future research should investigate additional factors such as stocking density, breed variations, seasonal influences, and other management practices across different production systems to optimize productivity and welfare in backyard poultry farming.

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