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Research Article

A Study of Egg Quality, Fertility and Hatchability in Kashmiri Rhode Island Red Chicken Breed

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Abstract: The fertility and hatchability of the eggs are traits of economic importance in poultry production. The Kashmiri Rhode Island Red (RIR) breed maintained under an intensive management system by the Government Poultry Farm Chacksagher, Mirpur, was assessed to study productive performance. The birds were provided with a standard formulated chick mash throughout the brooding period, grower ration for an additional period and layers mash from 21 weeks onwards. The results revealed that up to week 40, Kashmiri RIR males and females had an average weight of 2.74 ± 0.05 kg and 2.02 ± 0.04 kg, respectively. The mean age at sexual maturity was found to be 148 ± 1.22 days. The overall egg production percentage was 72.21 ± 2.40 with mean egg weight 52.94 g, shape index 77.90%, shell weight 4.94 g, shell thickness 0.30 mm, albumen weight 28.88 g, and yolk weight 16.26 g. The albumen and yolk height were 6.51 and 16.26 mm, respectively. The fertility was 88.60% while hatchability was 93.48% based on fertile eggs. Significant positive correlations were observed between age/fertility (0.712), age/hatchability of fertile eggs (0.561), age/hatchability of all eggs (0.681), fertility/hatchability of fertile eggs (0.857), fertility/hatchability of all eggs (0.982) hatchability of fertile eggs/hatchability of all eggs (0.938). In contrast significant negative correlations were assessed between traits like age/dead in germ (-0.748), shape index/dead in shell (-0.798), dead in germ/fertility (-0.748), dead in germ/hatchability of fertile eggs (-0.505) and dead in germ/hatchability of all eggs (-0.540). This study concluded that the Kashmiri RIR breed is an improved dual-purpose exotic breed which performs exceptionally well under intensive management systems in AJK, indicating its suitability for sustainable rural poultry production. The results provide a foundation for further genetic improvement programs and emphasize the importance of tailored management practices for optimizing productivity.

Keywords: Egg Quality, Fertility, Hatchability, Kashmiri Rhode Island Red, Chicken.

1. INTRODUCTION

Animal protein sources for the human population have been a significant concern in Azad Jammu and Kashmir (AJK), with reports indicating that many people are suffering from protein deficiency [1]. The World Health Organization (WHO) has estimated that the average daily requirement of animal protein is 27 grams per person. However, in Pakistan, this figure is significantly lower, with an average intake of only 17 grams per person. Notably, only 5 grams of these 17 grams of animal protein comes from poultry sources [2, 3]. Animal protein is a vital macronutrient that not only provides a complete profile of essential amino acids but also contains bioactive compounds critical for various physiological functions. Inadequate consumption of animal protein increases the risk of stunting, compromised immune systems, and impaired cognitive development, particularly in vulnerable populations such as children [4].

To address this issue, commercial chicken farming plays a critical role in meeting the protein demands of the region. The poultry sector in AJK has increasingly focused on exotic breeds due to

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their higher egg and meat production. These exotic breeds, along with their crossbreeds, are not only raised by farms but also by rural farmers. They are particularly popular in small households across rural, urban, and semi-urban areas of AJK due to their higher productivity compared to indigenous chicken breeds [5].

However, one of the major challenges in promoting commercial poultry farming in rural regions is the low adaptability of imported chicken breeds to the local climatic conditions. The exotic breeds need to be further studied to assess their full genetic potential and suitability for the region's environmental factors [6].

Previous studies have shown significant differences in the productive and reproductive performance of different chicken breeds. Exotic breeds, in particular, tend to show higher growth rates [7-9]. Fertility and hatchability are two critical aspects of reproductive performance, which are influenced by both genetic and environmental factors [10, 11]. Egg quality is another crucial factor affecting fertility and hatchability. Egg quality can be divided into external features, such as shell strength, and internal components like albumen height and yolk quality [12-14]. These traits vary between breeds and are vital for both consumer preference and the economic success of poultry farmers [15].

The poultry industry in Azad Jammu and Kashmir (AJK) has long been a neglected subsector within agriculture, facing challenges in meat and egg production, which result in lower returns and limited investment. The introduction of the Kashmiri Rhode Island Red (RIR) chicken breed, a dual-purpose exotic breed, could offer potential solutions to these persistent challenges. The Kashmiri RIR breed, introduced to AJK in 1975, has undergone nearly 200 generations of local production, resulting in a breed uniquely acclimatized to the region's environmental and management conditions. This breed is valued for its dual-purpose utility—providing both meat and eggs—as well as its adaptability to local rural poultry systems.

The adaptability of exotic breeds like RIR to local climatic conditions is essential for realizing their full genetic potential. Environmental factors such as temperature, humidity, and high-altitude terrain can significantly influence productivity and reproduction [16]. The Kashmiri RIR breed, however, represents a valuable genetic resource for rural communities in AJK due to its resilience, adaptability, and economic feasibility.

This study aims to systematically evaluate the egg quality, fertility, and hatchability of the Kashmiri RIR chicken, contributing to a deeper understanding of the breed's role in improving rural livelihoods and addressing regional protein deficiencies. The primary objective is to investigate the breed's acclimatization to local environmental conditions in AJK after generations of controlled breeding. Specific goals include: (i) assessing the external and internal egg quality characteristics, including weight, shell thickness, albumen height, and yolk color, were analyzed to determine their impact on hatchability and fertility, (ii) evaluating reproductive Performance to understand how effectively the breed reproduces under intensive management conditions; and (iii) exploring genetic and environmental interactions to determine how well the breed has adapted to AJK's climatic and management conditions.

By introducing the Kashmiri RIR breed, this research aims to stimulate increased interest, investment, and transformative change within the poultry sector in AJK. The findings are expected to provide actionable insights that will help optimize management practices, formulate strategies for sustainable poultry production, and ultimately address both economic and nutritional challenges in the region.

2. MATERIALS AND METHODS

2.1. Study Area

To study the productive and reproductive performance of RIR chicken along with the egg traits, data was collected from the Government Poultry Farm Chacksagher, Mirpur, located between latitude 33° 8' 54.2112'' N and longitude 73° 45' 6.3720'' E, lies at the foothills of the Himalayas mountain range of an altitude of 648 meters or 2,126 feet above sea level [17]. Mirpur has a humid subtropical climate. The average annual temperature is 25.1 °C. The average annual rainfall is 1,380 millimeters or 54.3 inches [18]. The farm covers an area of approximately 5 acres and has a capacity of housing 1,500 birds at a time. It is equipped with separate housing units for different age groups, semi-automated feeders, drinkers, and environmental control systems to maintain optimal temperature and humidity. The farm provides a controlled environment conducive to scientific research on poultry breeds.

2.2. Intensive Housing System

The 1024 birds of the Kashmiri RIR breed were kept at a comfortable temperature and humidity level with sufficient space and adequate ventilation. Straw was spread out on the floor to serve as an absorbent for the faecal droppings. Newly hatched chicks were nurtured in an electrically heated brooder for three weeks. The male and female ratio was kept at 1:10 at sexual maturity. Birds were provided with a standard formulated chick mash throughout the brooding period. During the growing phase, a grower ration was used, followed by layers mash from 21 weeks onward. This systematic feeding ensured nutritional adequacy for optimal growth and production.

2.3. Study Design

2.3.1. Body weight

Body weight (in kilograms) for both sexes was recorded weekly from one week to 40 weeks of age using a digital spring balance. The mean body weight was then calculated for each measurement. The body weight gain was determined using the following formula [9]:

$$\text{Gain in body weight} = \text{Final body weight} - \text{Initial body weight}$$

2.3.2. Egg production traits and sexual maturity

Age and body weight at sexual maturity, number of live hens per day and number of eggs on the daily basis was recorded during the 60 weeks' trial. The eggs were collected twice daily, in the morning and evening and the egg number was counted. Age and body weight at sexual maturity were determined based on the appearance of the first egg, which was monitored daily until 50% of the flock started laying eggs. This point was considered the age of sexual maturity. Birds were weighed immediately upon the onset of egg production to record body weight at this stage. The egg production percentage was calculated using a formula (adopted from Khawaja *et al.* [9];

$$Egg\ production(\%) = \frac{Total\ no.of\ eggs}{Live\ hens\ per\ day} \times 100$$

2.3.3. External egg quality traits

A total of 20 eggs were chosen from each poultry shed and evaluated for external and internal quality traits. The external egg characteristics; egg weight (grams): by using a digital spring balance; egg length and width (millimeters): by using vernier calliper with the least count of 0.05 mm; shell weight (g) and thickness (mm): which was measured at three different points and the average of the three was taken; eggshell colour was monitored by visual comparison with an eggshell colour fan, a series of graded (1-15) standard colorimetric system; and egg shape index (SI) which is defined as ratio of the egg width to egg length was used to categorized egg shape. SI was calculated as described by Kumar *et al.* [19]:

$$Shape\ index\ (\%) = \frac{Egg\ width}{Egg\ length} \times 100$$

2.3.4. Internal egg quality traits

For the determination of internal egg quality, various traits were evaluated including albumen weight (g), albumen height (mm), yolk weight (g), yolk height (mm), yolk color and Haugh Unit. These traits are critical indicators of egg quality because they influence the egg freshness, nutritional value, hatchability and consumer preferences.

2.3.4.1. Albumen and yolk height:

Each egg was broken out onto a flat surface and then allowed to sit for five minutes. For the measurement of albumen and yolk height, a height/depth gauge with the least count of 0.01 mm was used.

2.3.4.2. Albumen and yolk weight:

After measuring the height of albumen and yolk, they were detached carefully and weighed separately using digital electronic balance.

2.3.4.3. Yolk color:

A Roche color fan, standard colorimetric scheme ranged 1-15, 1 being pale yellow and 15 being deep vivid reddish orange was used to record the yolk color of eggs. The fan was used by visually comparing the yolk color under natural light to the standardized color chart. The score was recorded by two trained observers to ensure consistency and minimize subjective bias.

2.3.4.4. Haugh unit (HU):

The Haugh unit (HU) was calculated by using two egg parameters namely, height of albumen and egg weight using the following formula [20]:

$$HU = 100 \log(AH + 7.6 - 1.7\, EW^{0.37})$$

Where, HU = Haugh Unit,
AH = Observed albumen height (mm), and
EW = egg weight (g)

2.3.5. Fertility and hatchability

The eggs were collected from the birds' sheds daily and transported for sorting out, excluding cracked, dirty or distorted. The eggs were then transported to the hatchery and stored at 16 °C with a relative humidity of 70–80% for the evaluation of fertility, hatchability, dead in shell, and dead germ percentage [21]. Eggs were automatically incubated in accordance with conventional temperature and humidity settings that were automatically checked [22] with automatic turning of eggs through 90° in the incubator after every two hours. Individual eggs were checked through candling on the 5th and 18th day of incubation to provide a precise evaluation of the embryo's developmental stage. Eggs without signs of embryo development were counted and removed to determine fertility percentage, as outlined by Khan *et al.* [23]. The rest of the eggs having live embryos were then shifted to the hatching chamber of the incubator. Hatching process started on 19th day and ended at 21st day, the chicks were removed and counted. The fertility is the proportion of the egg that develop viable embryo upon incubation and the hatchability is the percentage of the fertile egg that successfully hatch into chicks. The fertility (%) and hatchability (%) was calculated as described by Ahmedin and Mangistu [24]:

$$Fertility\ (\%) = \frac{Total\ fertile\ eggs}{Total\ eggs\ set} \times 100$$

$$Hatchability\ \%\ (fertile\ eggs) = \frac{Chicks\ hatched}{Total\ fertile\ eggs} \times 100$$

$$Hatchability\ \%\ (total\ eggs\ set) = \frac{Chicks\ hatched}{Total\ eggs\ set} \times 100$$

2.3.6. Statistical analysis

The data was expressed as mean ± Standard Error of Mean (SEM) and coefficient of variance (CV). The body weight, egg production traits, and egg quality parameters (both external and internal) were presented as mean ± SEM to summarize central tendency and variability. The CV was calculated for external traits such as egg weight, shell thickness, and shape index, as well as internal traits like albumen height, yolk weight, and Haugh unit, to assess the relative variability of these measurements. The fertility and hatchability of eggs were studied in percentages. The relationships between various egg quality traits and reproductive traits were analyzed using GraphPad Prism 6.01 software. Pearson's correlation coefficient was applied to measure the strength and direction of linear relationships between traits. Statistical significance will be declared at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1. Body Weight

The live body weight of Kashmiri RIR breed from week 1 to 40 along with average weight gain is presented in Table 1. In this study Kashmiri RIR chickens recorded a drastic increase in body weight up to week 25. From week 30, the body weight of RIR increases gradually (mainly in females) and remains noticeably constant for some weeks. This steadiness in body weight can be attributed to the management of an intensive housing system. Moreover, the birds were fed a controlled amount of feed by their age. The amount of feed was increased until week 21. After that the same amount of feed (114 g/bird) was provided to the chickens which could have been the reason for the control in their body weights. The fluctuations in body weight of both sexes concerning age are presented in Figure 1.

In contrast to the results of the current study, Rahman *et al.* [25] in Bangladesh reported Lower body weight for RIR being 1485.22 g at 24 weeks

Table 1. Mean ± SEM for body weight of Kashmiri RIR breed up to 40 weeks.

Age (weeks)	Body weight of males (kg)	Gain in body weight (males)	Body weight of females (kg)	Gain in body weight (females)
1	0.03 ± 0.001		0.03 ± 0.001	
2	0.05 ± 0.001	0.02 ± 0.001	0.05 ± 0.001	0.02 ± 0.001
3	0.10 ± 0.002	0.05 ± 0.002	0.10 ± 0.002	0.05 ± 0.002
4	0.17 ± 0.003	0.07 ± 0.003	0.17 ± 0.003	0.07 ± 0.003
5	0.24 ± 0.005	0.08 ± 0.006	0.22 ± 0.005	0.11 ± 0.001
6	0.33 ± 0.01	0.09 ± 0.01	0.28 ± 0.01	0.04 ± 0.009
7	0.42 ± 0.01	0.17 ± 0.03	0.36 ± 0.01	0.14 ± 0.03
8	0.52 ± 0.02	0.09 ± 0.02	0.43 ± 0.02	0.07 ± 0.02
9	0.74 ± 0.04	0.17 ± 0.01	0.55 ± 0.05	0.10 ± 0.04
10	0.89 ± 0.05	0.15 ± 0.06	0.71 ± 0.03	0.17 ± 0.04
11	0.89 ± 0.08	0.03 ± 0.13	0.79 ± 0.06	0.02 ± 0.09
12	1.12 ± 0.03	0.67 ± 0.15	0.87 ± 0.05	0.47 ± 0.16
13	1.30 ± 0.04	0.19 ± 0.05	0.96 ± 0.04	0.09 ± 0.04
14	1.51 ± 0.06	0.21 ± 0.06	1.01 ± 0.02	0.04 ± 0.03
15	1.57 ± 0.05	0.06 ± 0.06	1.15 ± 0.03	0.15 ± 0.03
16	1.68 ± 0.04	0.13 ± 0.07	1.24 ± 0.03	0.08 ± 0.05
17	1.88 ± 0.04	0.07 ± 0.10	1.38 ± 0.03	0.08 ± 0.06
18	2.06 ± 0.05	0.30 ± 0.06	1.51 ± 0.02	0.20 ± 0.04
19	2.06 ± 0.05	0.007 ± 0.02	1.55 ± 0.03	0.03 ± 0.02
20	2.06 ± 0.06	0.002 ± 0.03	1.56 ± 0.04	0.009 ± 0.02
21	2.20 ± 0.04	0.14 ± 0.05	1.66 ± 0.06	0.10 ± 0.08
22	2.20 ± 0.05	0.0005 ± 0.05	1.67 ± 0.05	0.009 ± 0.07
23	2.21 ± 0.09	0.007 ± 0.09	1.87 ± 0.06	0.20 ± 0.05
24	2.24 ± 0.06	0.03 ± 0.10	1.89 ± 0.09	0.02 ± 0.06
25	2.30 ± 0.07	0.06 ± 0.04	1.89 ± 0.04	0.003 ± 0.06
26	2.36 ± 0.08	0.06 ± 0.009	1.89 ± 0.05	0.005 ± 0.01
27	2.43 ± 0.10	0.07 ± 0.04	1.89 ± 0.05	0.0005 ± 0.05
28	2.43 ± 0.09	0.002 ± 0.10	1.92 ± 0.10	0.03 ± 0.09
29	2.46 ± 0.07	0.03 ± 0.09	1.92 ± 0.06	0.002 ± 0.12
30	2.52 ± 0.07	0.06 ± 0.03	1.92 ± 0.06	0.0005 ± 0.03
31	2.53 ± 0.06	0.009 ± 0.03	1.93 ± 0.07	0.009 ± 0.06
32	2.55 ± 0.05	0.02 ± 0.03	1.95 ± 0.11	0.02 ± 0.06
33	2.60 ± 0.06	0.05 ± 0.03	1.95 ± 0.06	0.001 ± 0.06
34	2.66 ± 0.08	0.05 ± 0.03	1.97 ± 0.04	0.01 ± 0.06
35	2.66 ± 0.07	0.004 ± 0.09	1.97 ± 0.06	0.005 ± 0.03
36	2.66 ± 0.07	0.004 ± 0.08	1.97 ± 0.08	0.001 ± 0.03
37	2.67 ± 0.08	0.01 ± 0.11	1.96 ± 0.05	-0.006 ± 0.09
38	2.66 ± 0.09	-0.002 ± 0.07	2.01 ± 0.09	0.05 ± 0.11
39	2.67 ± 0.11	0.007 ± 0.15	2.02 ± 0.05	0.004 ± 0.11
40	2.74 ± 0.05	0.07 ± 0.13	2.02 ± 0.04	0.002 ± 0.06

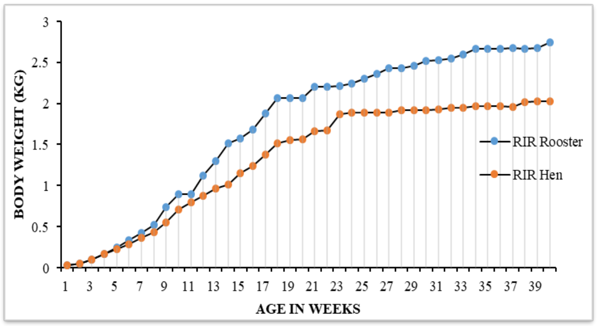

Fig. 1. Relationship between age and body weight in Kashmiri RIR breed.

of age and 1384.44 g at 40 weeks of age. Khawaja *et al.* [8] in Pakistan also recorded lower final body weight (1640 g), body weight gain (1608 g) in RIR up to 20 weeks. Weight gain in RIR chicken during the first 20 weeks was 1257.76 ± 4.52 in Rawalpindi, Pakistan [26]. Nowier *et al.* [27] showed that RIR in Egypt recorded body weight of 2207.25 ± 98.82, 2224.00 ± 66.89 and 2299.73 ± 70.7 g at 34^{th}, 38^{th} and 42^{nd} week of age, which is lower as compared to the figures obtained in the present study.

It was discovered that poultry production varies from farm to farm; it is influenced by several factors, namely, the number of birds on the farm, the mortality rate, the quality and quantity of feed consumed, the temperature range, seasonal fluctuations, and the ratio of pure breeds [9]. Gholami *et al.* [28] obtained the highest production for broiler chickens in an alpine climate. The climate of AJK is warm in summer and cold in winter and can be classified as a subtropical highland type [18]. The current study's findings may lead to the conclusion that better production performance was recorded for RIR in summer and winter in the subtropical climate.

3.2. Egg Production Traits and Sexual Maturity

Egg production is the yield of a bird's total performance regarding factors like egg number, rate of lay, age at sexual maturity, and characteristics of the eggs' quality [27]. The egg production and quality traits in Kashmiri RIR breed are summarized in Table 2. The mean age at sexual maturity of RIR was found to be 148 ± 1.22 days in the current study. Similarly, Khawaja *et al.* [9] reported that for the RIR breed the age at sexual maturity is 147 ± 1.15 days. The mean age at sexual maturity, 50% egg production and peak egg production were summarized to be 252.5, 273.3 and 294.5 days, respectively, in Bangladesh [29]. Maturity occurs at a specific age and body weight and is influenced by a variety of factors such as nutrition, temperature, light intensity, and many others [9]. The average body weight at sexual maturity for Kashmiri RIR hens was calculated to be 1.69 ± 0.03 kg. In contrast, lower body weight of RIR at sexual maturity (1296.3 g) and peak egg production stages (1538.8 g) was reported in Bangladesh [29]. In Rawalpindi RIR, Khawaja *et al.* [9] recorded 41% egg production in RIR breed which is much lower than that of present study (72.21 ± 2.40%; Table 2).

3.3. External Egg Quality Traits

3.3.1. Egg weight

The mean egg weight of Kashmiri RIR in the present study was 52.94 ± 0.35 g (Table 2). Similar value of mean egg weight for RIR was reported in Pakistan by Ashraf *et al.* [6] being 53.10 ± 0.30 g and Farooq *et al.* [12] being 53.94 ± 0.69 g while higher mean egg weight was presented in other studies conducted in Ethiopia (55.56 ± 1.79 g) [19], Egypt (56.29 ± 0.99 g) [27], and Slovak Republic (57.60 ± 0.76 g) [30], for RIR breed. In contrast, lower mean egg weight was reported for RIR being 49.07 ± 0.60 g under intensive management in Pakistan [31]. Amao [32] also indicated low average egg weight for the RIR genotype i.e., 48.02 g. The difference in egg weights between different studies could be due to many factors such as age, management, egg production level, and agroecological conditions.

3.3.2. Egg length and width

The mean values of egg length and width of Kashmiri RIR hens recorded in this study were 5.37 ± 0.02 cm and 4.18 ± 0.009 cm, respectively. The findings of this study are consistent with Farooq *et al.* [12] who recorded the mean egg length and width for RIR as 5.57 cm and 4.19 cm, respectively, in Pakistan. Hanusova *et al.* [30] in Slovak Republic summarized almost similar figures of egg length (5.62 ± 0.03 cm) and egg width (4.21 ± 0.02 cm) for RIR. The range of egg length (5.65 ± 0.17 cm) and width (4.38 ± 0.11 cm) for eggs of RIR reported by Kumar *et al.* [19] in Ethiopia was higher. However, lower mean values were recorded for egg length and width in RIR kept under intensive management in Pakistan [31].

Table 2. Mean ± SEM of egg production and quality traits in Kashmiri RIR breed.

Traits	Mean ± SE
Age at sexual maturity (days)	148 ± 1.22
Average body weight at sexual maturity (kg)	1.69 ± 0.03
Egg production (%)	72.21 ± 2.40
External egg quality traits	
Egg weight (g)	52.94 ± 0.35
Egg length (cm)	5.38 ± 0.02
Egg width (cm)	4.18 ± 0.009
Eggshell thickness (mm)	0.30 ± 0.003
Eggshell weight (g)	4.94 ± 0.03
Eggshell color	9.23 ± 0.17
Shape index (%)	77.90 ± 0.20
Internal egg quality traits	
Albumen height (mm)	6.51 ± 0.08
Yolk height (mm)	15.28 ± 0.16
Albumen weight (g)	28.88 ± 0.21
Yolk weight (g)	16.26 ± 0.11
Yolk color	7.232 ± 0.08
Haugh unit	82.57 ± 0.53

3.3.3. Egg shell quality

The quality of eggshell is determined by weight, thickness, percentage and strength. Eggshell quality varies depending upon environmental factors, feed quality, and chicken genotype [27]. In the present study, mean eggshell thickness was found out to be 0.30 ± 0.003 mm (Table 2). The findings of the present study are consistent with the results obtained by Khawaja *et al.* [9] who reported the eggs of RIR breed with eggshell thickness of 0.29 ± 0.13 mm. Higher eggshell thickness in RIR was reported in Pakistan by Farooq *et al.* [12] (0.39 ± 0.01 mm), Ashraf *et al.* [6] (0.36 ± 0.004 mm) and Nowier *et al.* [27] (0.41 ± 0.04 mm). The lower values of eggshell thickness in the present study could be attributed to the lack of nutrients in the diet as well as fluctuations in the environmental conditions. Eggshell thickness should be between 0.33 and 0.35 mm for the best hatchability [33]. Poor or thin shelled eggs have less chance of hatching. Ahmed *et al.* [34] reported that thick shelled eggs have a higher percentage hatchability (78.85%) than thin-shelled eggs (67.76%).

The mean eggshell weight (4.94 ± 0.03 g) documented for Kashmiri RIR (Table 2) was lower than that observed for RIR being 5.45 ± 0.12 g in Egypt [27], and 6.21 ± 0.06 g in Slovak Republic [30]. In contrast, Farooq *et al.* [12] in Peshawar, Pakistan presented lower mean eggshell weight for RIR (4.77 ± 0.09 g). The mean eggshell colour of the Kashmiri RIR breed presented in this study was 9.23 ± 0.17. The eggshell colour recorded in this study varied between the ranges of 5-14.

3.3.4. Shape index

Eggs have different shapes which can be differentiated using the shape index. The most often encountered egg shapes are sharp, normal (standard) and round, which were labelled on the shape index (SI) scale as <72, 72-76, and >76, respectively [35]. In the present study, the shape index of eggs was 77.90 ± 0.20 which was higher than 76 on the SI scale, hence the eggs are categorized as round. Nowier *et al.* [27] in Egypt and Kumar *et al.* [19] in Ethiopia also reported round shapes for RIR eggs with 76.74 and 78.43 egg shape index, respectively. In contrast, Ali and Anjum [31] recorded a standard shape with SI equal to 73.08 for RIR under the intensive system in Pakistan.

3.4. Internal Egg Quality Traits

3.4.1. Albumen and yolk height

Mean albumen and yolk height in Kashmiri RIR was found to be 6.51 ± 0.08 mm and 16.26 ± 0.11 mm (Table 2). The results compiled by Hanusova *et al.* [30] support the findings of the present study who reported RIR eggs in temperate regions to have yolk height of 16.97 ± 0.43 mm. Higher mean albumen and yolk height in RIR being 7.87 ± 0.65 mm and 17.34 ± 0.76 mm was reported in Ethiopia [19]. Khawaja *et al.* [9] proposed that the RIR breed produces eggs with average albumen height of 0.90 ± 0.07 cm in Pakistan. High thermal stress negatively affects albumen height and yolk leading to lower values of albumen and yolk height, hence ultimately Haugh unit decreases [36].

3.4.2. Albumen and yolk weight

The mean albumen and yolk weights recorded in this study were 28.88 ± 0.21 g and 16.26 ± 0.11 g, respectively. In Rawalpindi, Pakistan the RIR breed produced eggs with higher albumen (32 ± 1.15 g) and yolk (20 ± 0.28 g) weight as compared to that of the present study [9]. The RIR breed in central Europe with temperate climate was documented to produce eggs with heavier albumen (32.78 ± 0.73 g) and yolk (18.61 ± 0.20 g) as compared to the Kashmiri RIR breed of the present study found in subtropical climate conditions [30]. Nowier *et al.* [27] recorded higher values of albumen (34.95 g) and yolk weight (18.8 g) in Egypt. In contrast, Islam and Dutta [37] reported lower yolk weight (11.20 g) but heavier albumen weight (36.10 ± 4.46 g) in tropics.

3.4.3. Yolk colour

The most important aspect in any consumer survey pertaining to egg quality is the yolk colour [38]. Mean yolk colour of RIR was found to be 7.23 ± 0.08 according to Roche colour fan (Table 2). Kumar *et al.* [18] reported higher mean yolk colour being 9.25 ± 2.75 for RIR. In temperate regions, RIR eggs were observed to have darker yolk (11.10 ± 0.20) as documented by Hanusova *et al.* [30]. Supplemented maize makes a significant contribution to improved yolk colour intensity among feed ingredients. As a result, if a hen has access to green grass or supplemented feed ingredients containing carotenoids or xanthophylls, it will be sufficient to give the yolk the desired colour [39].

3.4.4. Haugh unit (HU)

Good quality eggs have a higher value of haugh units [40]. The haugh unit value for Kashmiri RIR was figured out 82.57 ± 0.53 which was almost consistent with the HU values recorded for RIR being 83.67 ± 3.78 in Egypt [19]. Some studies in UK have shown that for eggs with haugh unit below 60 there is a consumer resistance [41]. The results of this study were in contrast with the higher HU values reported in many previous studies in Pakistan and Egypt being 102.57 ± 0.59 and 87.96 ± 0.70, respectively [6, 27]. As compared to our findings, Monira *et al.* [13] discovered that fresh RIR eggs have a lower haugh unit.

3.5. Correlation among Various Traits for Kashmiri RIR Breed

The correlation assessment between various production and egg quality traits for Kashmiri RIR breed is presented in Table 3. The total of 105 correlations (between all combinations) were assessed, 56 were found positive and 38 were negative and 11 show no correlation. The significant positive correlations were found between Age/body weight (BW 0.83, P = 0.0001), Age/Yolk weight (0.74, P = 0.02), Egg weight/egg length (0.73, P = 0.02), Egg weight/egg width (0.72, P = 0.02), Egg weight/shell weight (0.88, P = 0.001) and Egg length/shell weight (0.83, P = 0.004) and Egg width/shell weight (0.71, P = 0.02).

Hailemariam *et al.* [42] reported that egg weight correlates positively and significantly with egg length (0.987), egg width (0.984) and eggshell weight (ESW; 0.964) for different chicken breeds in Ethiopia. The results showed that egg weight positively influences external quality traits in Kashmiri RIR hens. Non-significant correlations of EW with ESW were reported for RIR in tropics [37].

Non-significant positive correlations of egg weight and body weight (0.42) were in accordance with the results documented by Barua *et al.* [29] in RIR and Dana *et al.* [43] in Horro chicken of Ethiopia. Given that both criteria were found to be positively correlated in the current study, the production of eggs with higher egg weights in the Kashmiri RIR breed can also be attributable to increased body weight.

Verma *et al.* [44] assessed significant positive correlations ($P<0.01$) between egg shape index and egg weight in Aseel and Kadaknath hens which conflicts with the nonsignificant negative correlation of shape index and egg weight of current findings. In contrast with the findings of the present study, Farooq *et al.* [12] and Zita *et al.* [45] mentioned non-significant and positive correlations between egg weight and eggshell thickness.

The positive correlations of egg weight with internal egg quality traits such as albumen and yolk weight reported by Khawaja *et al.* [46] are in accordance with the results of the current study (0.42, 0.30, respectively). The results showed that larger eggs would have heavier albumens and yolks. Positive correlations of EW with albumin weight (AW; 0.96) and yolk weight (YW; 0.72) were also reported in the tropics [37]. Hailemariam *et al.* [42] also summarized similar results for correlations of

Table 3. Correlation among various productive and reproductive traits of Kashmiri RIR breed.

	Age	EPP	BW	EW	EL	EWD	ESW	EST	ESC	SI	AW	AH	YW	YH	YC	HU
Age	1															
EPP	-0.061	1														
BW	0.834***	0.326	1													
EW	0.361	0.769	0.422	1												
EL	0.327	-0.25	0.121	0.735**	1											
EWD	0.132	-0.23	-0.110	0.725**	0.548	1										
ESW	-0.153	0.090	-0.256	0.887***	0.840**	0.719*	1									
EST	0.374	-0.26	0.134	-0.089	-0.101	0.380	-0.10	1								
ESC	-0.263	-0.07	-0.71**	0.193	-0.032	0.334	0.258	0.363	1							
SI	-0.209	0.044	-0.205	-0.107	-0.547	0.398	-0.21	0.518	0.377	1						
AW	-0.303	0.006	-0.575	0.427	0.252	0.561	0.557	0.032	0.806	0.287	1					
AH	-0.465	0.472	0.048	0.680	0.761	0.119	0.877	-0.62	-0.56	-0.95	-0.77	1				
YW	0.748**	-0.61	0.395	0.302	0.406	0.409	0.096	0.562	-0.20	-0.03	-0.26	0.280	1			
YH	0.005	-0.35	-0.947	0.019	-0.248	0.007	-0.09	0.790	0.921	0.291	0.525	-0.20	-0.12	1		
YC	-0.338	0.123	-0.385	0.385	0.168	0.506	0.495	-0.32	0.249	0.294	0.561	-0.68	-0.45	0.848	1	
HU	-0.839	0.892	0.375	0.138	0.292	-0.446	0.446	-0.42	-0.65	-0.63	-0.98**	0.819	-0.27	-0.35	-0.761	1

*P ≤ 0.05, **P ≤ 0.01, ***P ≤ 0.001

BW = Body weight (g), EPP = Egg production percentage, EW = Egg weight (g), EL = Egg Length (cm), EWD = Egg width (cm), ESW = Eggshell weight (g), EST = Eggshell thickness (mm), ESC = Eggshell color, SI = Shape Index (%), AW = Albumen weight (g), AH = Albumen height (mm), YW = Yolk weight (g), YH = Yolk height (mm), YC = Yolk color, HU = Haugh Unit.

EW with albumen (0.891) and yolk (0.657) weight. The negative correlation between albumen height and albumen weight (-0.20) found in this study was contradictory to the results of Begli *et al.* [47] who reported high positive correlations of albumen height with albumen weight (0.52). Khawaja *et al.* [46] also assessed the positive and significant correlation of albumen height/albumen weight (0.768) and albumen height/yolk weight (0.699), non-significant positive ($P < 0.05$) correlations between albumin height and shell thickness (0.019).

In the present study, positive but non-significant correlations were observed between albumen height and egg weight (0.67) while Scott and Silversides [48] reported significant positive correlations between these two quality traits. Khawaja *et al.* [46] also mentioned significant and positive correlations between albumen height and egg weight (0.772, $P < 0.01$). The significant negative correlations were found between BW/shell colour (-0.71, $P = 0.03$) and albumen weight/HU (-0.98, $P = 0.01$). In the present study, it was observed that there is a negative non-significant correlation (-0.60) of age with egg production. This implies that as the age of the birds increases, the egg production percentage decreases as presented in Figure 2. These findings are consistent with those of Joyner *et al.* [49].

3.6. Fertility and Hatchability

During the four months period, from January to April, 22600 eggs of RIR breed were selected to evaluate the fertility and hatchability percentages.

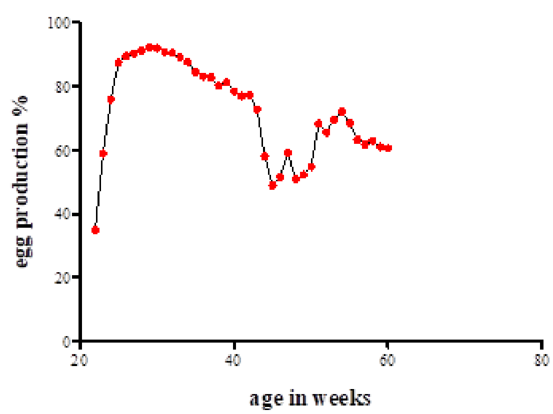

Fig. 2. Correlation between age and egg production in Kashmiri RIR.

Among the total, 2584 eggs were considered unsuitable and removed due to abnormalities, very small size, or poor quality of eggshells, giving 20016 eggs which were considered fertile and suitable for hatching (Table 4).

3.6.1. Fertility

In this study the mean fertility percentage was 88.60 ± 0.55 for RIR eggs. Less fertility percentage (83.53%) was recorded in the 1st hatch group whereas highest fertility percentage (91.08%) was recorded in the 16th hatch group. The findings of Islam *et al.* [50] for fertility percentage (88.29%) support the current results. Ashraf *et al.* [6] in Faisalabad, Pakistan reported higher values of fertility percentage (96.87 ± 1.53). Studies conducted in other countries like Tanzania also recorded higher (91.1%) fertility [51]. In contrast, lower figures for percentage fertility i.e., 53.06% and 78.26% were recorded in Peshawar and Rawalpindi, Pakistan [12, 23]. The higher percentage fertility of RIR can be attributed to its genetic makeup and capability of transferring this trait to the next generations. In the present study, there was a slight variation in fertility levels between the sixteen egg hatch groups. Various studies have shown that fertility within the same breed can vary due to a variety of factors such as management and male-to-female ratio [51].

3.6.2. Hatchability

The mean percentage hatchability of the fertile eggs and all eggs in the egg set for RIR was found out to be 93.48 ± 0.31 and 82.85 ± 0.76%, respectively (Table 4). The results of the current study are in contrast with that of Farooq *et al.* [12] who recorded hatchability percentages of 80.77 ± 0.10 and 42.86 ± 0.07 for fertile eggs and total eggs set, respectively, in Peshawar, Pakistan. Hatchability is determined by fertility and egg quality. Among fertile eggs, the mean hatchability for the RIR breed was revealed to be 64.0% in Tanzania [51], which is lower as compared to the hatchability percentage of RIR reported in the current study. Islam *et al.* [50] also presented a lower hatchability percentage of fertile eggs (88.37%) as compared to all eggs (79.57%). According to the current study, the hatchability of fertile eggs is higher than the hatchability of all eggs. The higher hatchability percentage for RIR recorded in the present study could be attributed to the good management factors of egg collection,

Table 4. Percentage of fertility and hatchability in Kashmiri RIR for year 2022.

Date of hatch	Eggs set (n)	Fertile eggs (n)	Chicks hatched (n)	Fertility (%)	Hatchability of fertile eggs (%)	Hatchability of all eggs (%)
2nd Feb	1500	1253	1145	83.53	91.38	76.33
9th Feb	1500	1286	1175	85.73	91.37	78.33
16th Feb	1500	1317	1225	87.80	93.01	81.67
23rd Feb	1500	1303	1193	86.87	91.56	79.53
2nd Mar	1500	1331	1250	88.73	93.91	83.33
9th Mar	1500	1318	1240	87.87	94.08	82.67
16th Mar	1500	1349	1281	89.93	94.96	85.40
23rd Mar	1500	1363	1292	90.87	94.79	86.13
30th Mar	1500	1357	1283	90.47	94.55	85.53
6th Apr	1500	1332	1236	88.80	92.79	82.40
13th Apr	1200	1035	955	86.25	92.27	79.58
20th Apr	1200	1057	996	88.08	94.23	83.00
27th Apr	1300	1176	1114	90.46	94.73	85.69
5th May	1300	1178	1110	90.61	94.23	85.38
11th May	1300	1177	1106	90.54	93.97	85.08
18th May	1300	1184	1112	91.08	93.92	85.54
Total	22600	20016	18713	88.60	93.48	82.85

handling, and storage on the farm level as the farmers with formal education in poultry husbandry were employed on poultry farm. Hatchability is also strongly influenced by egg size. Eggs that are too big or too little have a low hatchability rate and cause problems during the process of incubation [12]. Temperature and humidity, as well as egg turning, were well managed during the incubation process throughout the experimental period, resulting in better hatchability results in this study.

3.7. Correlation among Different Hatchability Traits

The correlation assessment between various hatchability traits for Kashmiri RIR breed ranged from -0.914 to 0.938. Significant positive correlations were observed between age/fertility (0.712, P = 0.002), age/hatchability of fertile eggs (0.561, P = 0.0235), age/hatchability of all eggs (0.681, P = 0.0037), fertility/hatchability of fertile eggs (0.857, P < 0.0001), fertility/hatchability of all eggs (0.982, P < 0.0001) hatchability of fertile eggs/ hatchability of all eggs (0.938, P < 0.0001) whereas, significant negative correlations were assessed between traits like age/dead in germ (-0.748, P = 0.0009), shape index/dead in shell (-0.798, P = 0.0317), dead in germ/fertility (-0.748, P = 0.0009), dead in germ/hatchability of fertile eggs (-0.505, P < 0.0001) and dead in germ/hatchability of all eggs (-0.540, P < 0.0001), dead in shell/hatchability of fertile eggs(-0.5036, P = 0.0468), dead in shell/ hatchability of all eggs (-0.5401, P = 0.0309) for Kashmiri RIR breed. The rest of all the correlations were found to be non-significant (Table 5).

The present study assessed nonsignificant negative correlations of egg weight/hatchability of fertile eggs (-0.410) and egg weight/hatchability of all eggs set (-0.526) which is in accordance with the findings of Farooq *et al.* [12]. This means that a higher egg weight may result in reduced hatchability. Medium sized eggs ranging from 51 to 55 g have higher fertility as compared to much larger or smaller eggs [52]. Verma *et al.* [44] mentioned positive correlations between shape index and hatchability of all eggs set for Aseel (0.986) and Kadaknath hens (0.998) which is in contrast with the negative correlations of shape index with hatchability of fertile eggs (-0.288) and hatchability of all eggs (-0.526) in Kashmiri RIR reported in this study. The findings of the present study suggest that increased egg length and width (resulting in higher shape index %) would result in decreased hatchability. Similar results were recorded by Farooq *et al.* [12] for RIR breed. The results obtained by Islam *et al.* [50] were in support of the present study as they also observed positive correlations of percentages of fertility with hatchability of fertile eggs and all eggs as well in RIR. Verma *et al.* [44] also reported positive correlations of fertility with hatchability of fertile eggs and hatchability of all eggs in (0.953, 0.980) and (0.968, 0.992) at P<0.01. The positive correlations of fertility and hatchability suggest that increased fertility ensures increased hatchability. This was also observed by Farooq *et al.* [12] in RIR hens.

This study was conducted under controlled conditions at a single government poultry farm, which may not fully reflect variability in rural or

Table 5. Correlation among different hatchability traits in Kashmiri RIR breed.

	Age	Egg weight	Shape index	Fertility	Dead in germ	Dead in shell	Hatchability of fertile eggs	Hatchability of all eggs
Age	1							
Egg weight	-0.659*	1						
Shape index	-0.041	-0.071	1					
Fertility	0.712**	-0.558	-0.2628	1				
Dead in germ	-0.748***	0.444	0.0902	-0.748***	1			
Dead in shell	-0.396	0.035	-0.797*	-0.533*	0.495	1		
Hatchability of fertile eggs	0.561*	-0.410	-0.288	0.857***	-0.914***	-0.504*	1	
Hatchability of all eggs	0.681**	-0.526	-0.284	0.982***	-0.834***	-0.540**	0.938***	1

*P ≤ 0.05, **P ≤ 0.01, ***P ≤ 0.001

commercial settings. Additionally, the sample size for some parameters, such as hatchability correlations, may limit the generalizability of the findings. Future studies should include multiple locations and larger sample sizes to validate these results.

4. CONCLUSIONS

In conclusion, the Kashmiri Rhode Island Red (RIR) breed has demonstrated strong adaptability and potential for both rural and commercial poultry systems in AJK. The breed shows consistent growth, optimal sexual maturity, and high-quality egg production, including favorable traits such as shell thickness, albumen height, and yolk colour. Furthermore, its fertility and hatchability rates confirm its viability under intensive management. The breed's adaptation to local environmental conditions makes it a valuable resource for improving protein production and supporting sustainable poultry farming in the region.

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6. ETHICAL STATEMENT

The ethical committee of the Board of Advanced Studies and Research of the University of Azad Jammu and Kashmir, Muzaffarabad, has approved this study with notification No. F-BASR/(82nd M)/19(i)-48/1609-10/2022, which is in accordance with the rules and regulations.

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