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Sensory Characteristics, Nutritional Composition, and Quality of Eggs from Different Chickens

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Abstract

The present study evaluated the sensory, composition, and quality of eggs from Cosmopolitan (C), Improved Horro (H), ♂ Improved Horro * Cosmopolitan ♀ (HC), ♂ Cosmopolitan * Improved Horro ♀ (CH), Indigenous(L), and Koekoek (KK) genotypes. A completely randomized design was used in the study. A total of 108 (18/genotype), 180 (30/genotype), and 90 (15/genotype) eggs were used for the sensory, composition, and egg quality tests, respectively. All data were analyzed following the GLM model using SAS software. The boiled and scrambled eggs from L, H, and C were ($P \leq 0.001$) preferred followed by CH, HC, and KK. Results showed that KK, HC, CH, and C eggs were higher in moisture, crude fat, crude ash, and crude fiber, but these traits were found lower in H and L genotypes. A significantly highest crude protein was observed in L (21.19 ± 0.19) genotype, with higher in H (20.62 ± 0.26), intermediate in HC (19.96 ± 0.29), C (19.85 ± 0.10), and CH (19.40 ± 0.37), whereas the eggs from KK genotype had the lowest crude protein content (18.69 ± 0.20). The egg quality was ($P = 0.001 - 0.01$) affected across traits except for eggshell indices ($P > 0.05$). The genotypes with a negative significant correlation with crude protein had a positive significant correlation with almost all composition and egg external quality traits. The genotypes with positive significant correlations of egg weight had positive significant correlations with most internal egg quality traits except that of yolk weight ratio, yolk albumen ratio, and yolk color. Conclusively: the eggs of L, H, and C genotypes were best favored followed by CH and C, but the KK genotype was the least favored, and these differences were deemed due to genetic variations, and interventions. Furthermore, the eggs laid from genotypes with deep yellow yolk color might be the most nutritious. It could also necessitate future breeding and dietary studies.

Keywords

Chicken, Sensory Characteristics, Nutritional Composition, Egg Quality, Correlation

1. Introduction

The sensory behavior, nutritional composition, and quality of a product can affect its acceptability to producers and consumers, whereas health and taste have been reported as important quality issues [1] [2]. Eggs have been noted as highly versatile, complete, and affordable food containing high protein, balanced vitamins, minerals, carotenoids, ω-3 fatty acids, ω-6 fatty acids, and relatively low-calorie and cholesterol [3] [4]. The growing demand of consumers in eating quality eggs has affected research direction in poultry science [5] [6]. Eggs from chickens of different genotypes, management, and nutrition could vary in sensory attributes, nutritional composition, and quality characteristics [7] [8].

Panelist acceptability has been explained as an important and practically plausible sensory quality assessment method of products from various chickens using human senses [9] [10]. Likewise, the flavor can be explained to represent both taste and smell while appearance can replace for sight and color of eggs [11]. Besides, an electronic nose system could detect volatile compounds with higher sensitivity but less psychological perception ability than humans do [12]. Volatile compounds of products can be analyzed by a gas chromatography-mass spectroscopy (GC-MS) and had enhanced the sensory quality though highly expensive and less feasible for a practical application than panelist and consumer implicating for their merits and demerits [13] [14] [15]. Moreover, an electronic tongue system can characterize product taste and improve sensory precessions [16]. However, it could be noted that laboratory sensors over panelists/consumers might be complicated and confirmed to be unaffordable besides complications to replacing human psychological senses and perceptions [17].

The nutritional composition and quality of eggs can be influenced by internal and external factors [18] [19]. Studies have revealed that egg nutritional composition can be explained by measures such as moisture, crude protein, crude fat, crude ash, and crude fibers of various products [20]. Egg quality is composed of those characteristics of an egg that affect its acceptability by consumers [21]. External egg quality is presented by its weight, shape, percentage of eggshell, and thickness which vary according to the species, breed, variety, feed, management, and environment as reported by the different researchers in different breeds [22]. Similarly, internal egg quality is presented by albumen quality and yolk quality which are responsible for the nutritional value of eggs of breeds and determine their acceptability to the consumers [23]. Moreover, Egg quality can be characterized by focusing on the eggshell of external and egg content of internal qualities [24] [25].

The genetically improved Horro genotype of Ethiopia (H) was reported to increase growth and egg production [26]. Moreover, the Cosmopolitan genotype (C) was stated as imported chicken and was considered the symbol of global chicken diversity. Further, the Koekoek (KK) dual-purpose chicken genotype was imported from South Africa [27] and these were used as imported references in this study. The indigenous chicken (L) was used as a reference following the selection and breeding description studies reported in [28]. As the cosmopolitan breed is newly imported to Ethiopia, it is evident that this genotype also demanded initial research information and documentation before dissemination and to serve as an input for future studies. Likewise, the Cosmopolitan (C), and Improved Horro (H) were directly and reciprocally crossed, Cosmopolitan ♂ * Improved Horro ♀ (CH), Improved Horro ♂ * Cosmopolitan ♀ (HC), with reasonably hypothesized variations among eggs of experimental hens, and these eggs from hens were compared in references to indigenous (L) and Koekoek (KK) eggs. Therefore, the objective of this initiated research was to investigate and compare the selected chicken genotypes on sensory characteristics, nutritional composition, and egg quality parameters.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted at Werer Agricultural Research Centre (WARC), 280 km away from Addis Ababa. The Werer Agricultural Research Center was found at an altitude of 820 meters above sea level and at 9˚55'N latitude and 40˚40'E longitude. The annual rainfall and average minimum and maximum temperatures for Werer Agricultural Research Center ranged from 400 mm to 600 mm, and 19.3˚C, and 45˚C, respectively.

2.2. Sampling Procedures and Experimental Animals

This experiment was managed following the guidelines approved by the institutional animal care and use committee (IACUC) and conducted jointly with the article reported by [28]. The experimental animals were namely, I = Improved Horro (H), II = Cosmopolitan (C), III = Koekoek (KK), IV = Indigenous (L), V = Cosmopolitan ♂ * Improved Horro ♀ (CH), and VI = Improved Horro ♂ * Cosmopolitan ♀ (HC). The watering and feeding troughs and laying nests were cleaned, disinfected, and sprayed against external parasites before the start of the experiment. The floor of each pen was bedded with disinfected grass hay and was replaced when deemed appropriate. All hens (indigenous and imported) used for this experiment were hatched on the same day. Hens were fed the same commercial starter, grower, and layer rations following their age phases (Alema koudjis; Feed Co., Ltd., Debrezeit, Ethiopia). Hens were vaccinated against

Newcastle, Gumburo (Infectious Bursal Disease-IBD), and Fowl Typhoid diseases using the appropriate vaccine according to the manufacturer's recommendation. Experimental Chickens were subjected to similar management under on-station conditions. Health Stata was monitored during the entire trial. Feed manufactured by Alema koudjis; Feed Co., Ltd., Debrezeit, Ethiopia was used during the entire trial period (Table 1) and supplements were given through drinking water. Pens were also equipped with laying nests provided all requirements.

2.3. Sensory Characteristics of Hardboiled and Scrambled Eggs from Different Genotypes

The eggs collected from on station within 24 hours and stored at 4˚C were used for the sensory evaluation study. The egg sensory trials were conducted to determine the score of acceptance of both scrambled and hardboiled eggs from KK, CH, HC, C, H, and L hens. The scrambled eggs were scheduled in the morning and the boiled egg in the afternoon to control sensory biasedness. There was the provision of drinking water for panelists to rinse their mouths after scoring each sample to minimize sensory carryover. A total of fifteen (7 male and 8 female) semi-trained panelists with ages ranging from 20-to-40 years and with no egg allergies and free of alcohol additions were used to taste in this study. Panelists were trained and pretested with egg sensory techniques using egg scoring sheets provided for grading the sensory trials. The panelists tasted and rated the eggs on a seven-point hedonic scale (7 = like very much; 1 = dislike very much), according to [29]. The hardboiled eggs of each chicken were cooked in boiling water for 15 min, inserted into cold water for 2 min, peeled, and divided into two equal parts. The scrambled eggs were beaten and stirred to homogenize the mixture. The scrambled eggs were cooked for 5 min at a temperature of 176.7˚C. A pre-warmed stainless-steel pan was used to cook the experimental eggs. A total of 96 (48 hardboiled and 48 scrambled edible trial eggs) eggs were served in three plates per genotype for both hardboiled and scrambled eggs having coded

Table 1. Nutrient composition of the diet fed to KK, HC, CH, C, H, and L chickens.

Nutrient	Starter	Grower	Layer
Metabolizable energy (Kcal/kg)	3000.00	2950.00	2800.00
Crude protein (% DM)	20.50	18.80	16.00
Crude fiber (% DM	5.50	5.80	7.00
Calcium (% DM)	0.90	0.90	3.55
Fat (% DM)	6.50	5.00	5.00
Moisture (%)	10.00	10.00	10.00

The feed composition of starter, grower, and layer provided by Alema Koudjis, Feed Co., Ltd., Debrezeit, Ethiopia, Cosmopolitan (C), Improved Horro (H), Cosmopolitan ♂ * ♀ Improved Horro (CH), Improved Horro ♂ * ♀ Cosmopolitan (HC), indigenous (L) and Koekoek (KK) chickens.

each plate with sample numbers to identify.

2.4. Nutritional Composition of Eggs from Different Genotypes

The nutritional composition of eggs was determined following the Association of Official Analytical Chemists methodology [30]. The moisture content was determined by drying the samples at 105˚C to constant weight. The crude protein content was determined by the Kjeldahl method, and the crude fat content was determined by the Soxhlet method. The ash content was determined by charring followed by ash the samples at 550˚C to white ash. A total of 180 eggs and 30 eggs from each genotype were used to determine the nutritional composition of the chickens.

2.5. Eggs quality of Different Genotypes

A total of 90 eggs were used to measure the egg quality traits. The external egg characteristics were determined by egg weight (g), egg length and width (mm), shell weight (g) and thickness (mm), egg shape index (%), and shell weight ratio (%). The internal egg quality traits are albumen weight (g), albumen weight ratio (%), albumen height (mm), yolk weight (g), yolk weight ratio (%), yolk height (mm), yolk width, yolk Index, yolk color, yolk: Albumen ratio and Haugh Unit (%). Eggs were individually weighed to the nearest 0.01 g using an electronic digital balance. The length and width of the egg were individually recorded by using a digital caliper. The shape index was calculated by the formula (width/length) × 100. The shell thickness was measured at three (blunt, middle, and sharp) points of the egg and the calculated average of the three was used. To determine the internal egg quality traits, eggs were broken onto a flat surface. Yolk height and albumen height were measured using a spherometer. Albumen and yolk were carefully detached with the aid of a spatula and weighed separately. Albumen and yolk weight was determined by weighing with electronic balance separately. The yolk color was determined using the Roche color fan (1 - 15). The Haugh Units (HU) were calculated from the two parameters; the height of albumen (AH) and egg weight (EW) using the formula: $HU = 100\log(AH - 1.7\,EW^{0.37} + 7.57)$, where HU = haugh unit, AH = thick albumen height in mm and EW = egg weight in gram.

2.6. Statistical Analyses

The data was recorded as per the prepared sheet and was entered into excel regularly. The data collected was summarized and analyzed by the GLM model using SAS software (SAS, 2004). When the GLM showed a significant difference at $P < 0.05$, Duncan's multiple range tests were used for mean separation.

The model used for the analysis was:

$$Yik = \mu + Gi + eik$$

where,

Yik = the response variables

μ = the overall Mean

Gi = the effect of genotype, eik = Random error

3. Results and Discussion

3.1. Sensory Characteristics of Hardboiled and Scrambled Eggs of Laying Genotypes

The sensory characteristics of hardboiled and scrambled eggs of laying genotypes are presented in **Table 2**. Significantly higher ($P \leq 0.001$) hardboiled egg flavor scores were observed in L (6.53 ± 0.05), H (6.36 ± 0.10), and C (6.22 ± 0.13) followed by CH (5.86 ± 0.15), KK (5.83 ± 0.08) and (5.72 ± 0.11) eggs. Scholars approved that significantly ($P < 0.05$) lower aroma scores were detected in HLW (3.93) than in R (6.60) breeds, whereas HLB (5.07) and E (5.58) breeds scored intermediate for that profile [31]. Besides, significantly ($P < 0.05$) higher hardboiled egg odor scores were observed in E (6.62) eggs than in HLB (4.88), HLW (4.13), and R (3.63) eggs. Further, hardboiled egg flavors were observed significantly highest for WLH (10.6 ± 0.64), intermediate for WPR (9.3 ± 0.59), NN (9.3 ± 0.76), RIR (8.6 ± 0.61), Fayoumi (7.8 ± 0.66) whereas, significantly lowest flavor (6.6 ± 0.79) was scored in Aseel eggs [32]. The flavor scores from Beinong eggs were observed significantly ($P < 0.05$) higher than that of Hy-Line Brown and Wuhei eggs [15]. The hardboiled egg flavors might be varied due to differences in amino acid and fatty acid compositions [33]. Likewise, single nucleotide polymorphism of fatty acid desaturase1 could enhance egg flavor intensity and continuity, while negatively correlated with n-6/n-3 ratios [34]. Similarly, free amino acid profiles of Araucana eggs were significantly varied in egg flavor as compared to Ukokkei, Nagoya, Kurohisui, and Boris Brown egg flavors [35]. The hardboiled egg flavor differences could be attributed to variations in dry matter contents of eggs in laying hens [36]. In addition, heritable epigenetics, relating to the non-genetic influence on gene expression of tissue and genotype had

Table 2. Sensory characteristics of scrambled and hardboiled eggs of KK, HC, CH, C, H, and L chickens.

Category	**Genotype(G)**						**P-value**
	KK	**HC**	**C**	**CH**	**H**	**L**	**G**
Parameter	**Mean ± SE**						
Flavor$_1$	5.83 ± 0.08^{b}	5.72 ± 0.11^{b}	6.22 ± 0.13^{a}	5.86 ± 0.15^{b}	6.36 ± 0.10^{a}	6.53 ± 0.05^{a}	***
APP$_1$	5.39 ± 0.11^{c}	5.67 ± 0.10^{cb}	6.17 ± 0.13^{a}	5.81 ± 0.14^{b}	6.28 ± 0.11^{a}	6.39 ± 0.08^{a}	***
OA$_1$	5.76 ± 0.05^{c}	5.89 ± 0.09^{c}	6.22 ± 0.12^{ba}	5.94 ± 0.14^{bc}	6.23 ± 0.11^{ba}	6.48 ± 0.10^{a}	***
Flavor$_2$	5.75 ± 0.05^{c}	5.87 ± 0.09^{c}	6.25 ± 0.10^{b}	5.97 ± 0.10^{c}	6.40 ± 0.08^{ba}	6.56 ± 0.06^{a}	***
APP$_2$	5.56 ± 0.06^{c}	5.73 ± 0.07^{cb}	6.20 ± 0.14^{a}	5.90 ± 0.12^{b}	6.37 ± 0.09^{a}	6.45 ± 0.04^{a}	***
OA$_2$	5.75 ± 0.03^{c}	5.80 ± 0.07^{c}	6.21 ± 0.11^{b}	5.94 ± 0.10^{c}	6.34 ± 0.07^{ba}	6.51 ± 0.05^{a}	***

^{abcd}Mean under the same category bear different superscript letters are significantly different, *** = $P < 0.001$, SE = Standard error, Flavor$_1$ = Scrambled Egg Flavor, APP$_1$ = Scrambled Egg Appearance, OA$_1$ = Scrambled Egg overall Acceptance, Flavor$_2$ = Boiled Egg Flavor, APP$_2$ = Boiled Egg Appearance, OA$_2$ = Boiled Egg Overall Acceptance.

significant ($P < 0.05$) affected egg flavors of white leghorn compared to Red Jungle Fowl [37]. The hardboiled eggs showed significantly highest ($P \le 0.001$) appearance scores in L (6.45 ± 0.04), H (6.37 ± 0.09), and C (6.20 ± 0.14) followed by CH (5.90 ± 0.12), HC (5.73 ± 0.07) and KK (5.56 ± 0.06) eggs. Significantly ($P < 0.0001$) highest appearances of egg color scores were confirmed in BrF (8.02 ± 1.80) and BlF (7.70 ± 1.28) than FR (6.03 ± 2.20) and WC (5.88 ± 1.70) hardboiled eggs (Jeniffer et al., 2020). Moreover, panelists confirmed that hardboiled Aseel eggs were found significantly ($P < 0.05$) lowest (5.10 ± 0.66) in color appearances than WLH (8.80 ± 0.64), NN (8.20 ± 0.67), WPR (7.30 ± 0.67), RIR (7.30 ± 0.57) and Fayoumi (7.10 ± 0.41) hen eggs laid by different breeds [32]. Furthermore, significantly ($P < 0.01$) highest color scores were observed in Ostrich (8.83 ± 0.17) breed eggs followed by Native chicken (7.67 ± 0.33) and Turkey (6.67 ± 0.33) breed eggs boiled and rated [38]. The eggs showed significant variation in the color scores and that might be due to the sources of pigmentation and physiological carotenoid precursors (natural or synthetic) [39]. Besides, egg color scores varied due to breed, epigenetics, and pigmentation precursors [2] [37] [38]. In the current sensory study, significantly highest ($P \le 0.001$) overall acceptability scores were observed for L (6.45 ± 0.04), higher for H (6.37 ± 0.09) and C (6.20 ± 0.14), high for CH (5.90 ± 0.12) but, lowest overall score preferences were obtained for HC (5.73 ± 0.07) and KK (5.56 ± 0.06) hardboiled eggs over breeds. The overall acceptability scores of hardboiled eggs were significantly highest for WLH (10.8 ± 0.49), intermediate for RIR (9.5 ± 0.64) but, the lowest panelist scores were observed for NN (9.3 ± 0.57), Fayoumi (8.6 ± 0.74), WPR (8.5 ± 0.49), 8.2 ± 0.62) and Aseel (8.2 ± 0.62) breed eggs [32]. However, overall acceptability scores were noted insignificantly ($P > 0.05$) varied among chicken (7.83 ± 0.48), Ostrich (7.67 ± 0.33), and Turkey (7.33 ± 0.33) eggs species [38].

Significantly lowest ($P \le 0.001$) scrambled egg flavor scores were observed for KK (5.83 ± 0.08), HC (5.72 ± 0.11), and CH (5.86 ± 0.15), intermediate for C (6.22 ± 0.13), higher for H (6.36 ± 0.10), whereas the highest flavor score was found for L (6.53 ± 0.05) eggs. Significantly ($P \le 0.001$) lowest egg appearance scores were approved for KK (5.39 ± 0.11), lower for HC (5.67 ± 0.10), low for CH (5.81 ± 0.14), higher for C (6.17 ± 0.13), whereas significantly highest egg appearance scores were obtained for H (6.28 ± 0.11) and L (6.39 ± 0.08) scrambled eggs. Significantly lowest ($P \le 0.001$) overall acceptability egg scores were confirmed in KK (5.76 ± 0.05) and HC (5.89 ± 0.09) hens, lower in CH (5.94 ± 0.14) hens, intermediate in C (6.22 ± 0.12) and H (6.23 ± 0.11) hens but the highest overall acceptability ratings scored in L (6.48 ± 0.10) scrambled eggs. In the current study, panelists observed significant differences between scrambled and boiled eggs and across laying breeds in contrast to the findings reported by [40]. In addition, the variability of the preference score of hardboiled and scrambled eggs might be due to genetic, epigenetic, and non-genetic factors such as the level of psychological perceptions of panelists and/or consumers (natural or synthetic), which is in line with the current findings [32] [39].

3.2. Nutritional Composition of Eggs of Different Chicken Genotypes

The nutritional composition of Eggs of different chickens was presented in Table 3. The moisture contents of eggs were significantly ($P \leq 0.05$) lowest for L (73.71 ± 0.27), lower for H (74.28 ± 0.30), and higher for HC (74.65 ± 0.37), C (74.76 ± 0.24), CH (74.86 ± 0.23) and KK (75.03 ± 0.24) across breeds. The moisture content was significantly ($P < 0.01$) higher in eggs of white Leghorn (75.41 ± 2.30) than that of Fayoumi (71.35 ± 1.91) laid eggs [41]. Moreover, eggs of E (1.80) had significantly higher ash content than HLW (1.72), R (1.71), and HLB (1.67) hen eggs [31]. However, the eggs from the Naked Neck showed significantly lower crude protein content (13.37) than that of Lohmann Brown due to genetic variation (14.56) [6]. The moisture content was significantly ($P < 0.001$) lower in Mos eggs (74.35) than in Isa Brown (77.40) eggs [42]. The difference in moisture content of hen eggs is attributed to variation in the genetic makeup across breeds. Also, the moisture content of eggs could be varied due to differences in evaporation rate, porosity, shelf life, bioactivity, and bodyweight sizes [43] [44]. A significant highest crude protein content was noted for L (21.19 ± 0.19), higher for H (20.62 ± 0.26), intermediate for HC (19.96 ± 0.29), C (19.85 ± 0.10), and CH (19.40 ± 0.37) eggs, whereas KK eggs showed the lowest crude protein content (18.69 ± 0.20). The eggs from the Mos breed had significantly ($P < 0.001$) higher crude protein than that of Isa Brown eggs (12.31% vs.11.66%) [42]. In contrast, a significantly ($P < 0.05$) lowest crude protein was recorded in local (19.45 ± 0.00), intermediate in crossbred (20.70 ± 0.01), whereas the highest was recorded in exotic (22.03 ± 0.00) breed eggs [45]. Hence, the variation in crude protein content is attributed to the differences in the egg-laying breeds [46]. A significantly ($P \leq 0.01$) highest crude fat was observed for KK (3.94 ± 0.07) and higher for CH (3.71 ± 0.07) eggs, whereas the lowest crude fat was recorded for C (3.54 ± 0.02), HC (3.50 ± 0.06), H (3.42 ± 0.03) and L (3.40 ± 0.03) breed eggs. Furthermore, significantly ($P < 0.05$) higher fat content was

Table 3. Nutritional composition of eggs of KK, HC, CH, C, H, and L chickens.

Category	Genotype(G)						P-value
	KK	HC	C	CH	H	L	G
Parameter	Mean ± SE						
Mo	75.03 ± 0.24^{a}	74.65 ± 0.37^{a}	74.76 ± 0.24^{a}	74.86 ± 0.23^{a}	74.28 ± 0.30^{ba}	73.71 ± 0.27^{b}	*
CP	18.69 ± 0.20^{d}	19.96 ± 0.29^{c}	19.85 ± 0.10^{c}	19.40 ± 0.37^{c}	20.62 ± 0.26^{b}	21.19 ± 0.19^{a}	**
Fat	3.94 ± 0.07^{a}	3.50 ± 0.06^{c}	3.54 ± 0.02^{c}	3.71 ± 0.07^{b}	3.42 ± 0.03^{c}	3.40 ± 0.03^{c}	**
Ash	0.71 ± 0.05^{a}	0.53 ± 0.04^{cb}	0.52 ± 0.02^{cb}	0.59 ± 0.04^{b}	0.43 ± 0.04^{c}	0.41 ± 0.03^{c}	**
CF	1.63 ± 0.11^{a}	1.36 ± 0.05^{b}	1.33 ± 0.05^{b}	1.44 ± 0.07^{ba}	1.25 ± 0.05^{b}	1.29 ± 0.01^{b}	**

^{abc}Mo = Moisture, CP = Crude Protein, Fat = Crude Fat, Ash = Crude Ash, CF = Crude Fiber, ** = $P < 0.01$, * = $P < 0.05$, Cosmopolitan (C), Improved Horro (H), Cosmopolitan ♂ * ♀ Improved Horro (CH), Improved Horro ♂ * ♀ Cosmopolitan (HC), indigenous (L) and Koekkoek (KK) Hens' eggs.

observed in Fayoumi than that of White leghorn breeds [4]. The fat content of egg of breeds have significantly varied (Exotic > Crossbred > Local) [45]. In contrast, a significantly ($P < 0.001$) lower crude fat content was observed in Isa Brown eggs than in Mos eggs [42]. The difference in fat content is attributed to the variation in the breeds and strains of eggs [6] [46].

The study discovered that eggs from KK were noted significantly ($P \leq 0.01$) highest in crude ash level (0.71 ± 0.05) followed by higher CH (0.59 ± 0.04), intermediate in HC (0.53 ± 0.04) and C (0.52 ± 0.02) than eggs from H (0.43 ± 0.04) and L (0.41 ± 0.03) hens. The NN eggs (0.95) revealed significantly ($P < 0.001$) higher crude ash content than LB (0.89) eggs [6]. Likewise, the crude ash was noted significantly lowest for commercial chicken (0.68 ± 0.06), lower for commercial quail (0.94 ± 0.14) and indigenous chicken (0.93 ± 0.09), whereas domestic guinea fowl (1.00 ± 0.07) and wild quail (1.03 ± 0.16) hen eggs were found significantly ($P < 0.001$) highest for that trait [46]. Likewise, Hybrid chicken eggs (1.32 + 0.03) were observed significantly ($P < 0.05$) higher in crude ash content than Domestic chicken (0.99 + 0.21) and Guinea fowl (0.70 + 0.12) eggs [20]. However, eggs from the Isa Brown hen breed had significantly ($P < 0.001$) lower crude ash content (1.04) than eggs from Mos (1.10) hen breed [42]. The variability of crude ash content of eggs might be attributed to differences in mineral content of different hen breeds [8]. Similarly, eggs from hen breeds with the highest mineral contents might greatly affect the physiological conditions of children, elders, and pregnant women [46]. Furthermore, eggs of hen breeds with the highest mineral content might highly influence the physiological functions of bones and teeth (Ca), transportation of oxygen (Fe), immunity maintenance (lutein and zeaxanthin nutrients), metabolic activities, DNA construction, and maintenance (Zn) of consumers from that egg breeds [47] [48]. Presumably, the difference in ash content might be attributed to the variation in the genetic sensitivity response of breeds that drank saline drinking water [49]. A significantly ($P \leq 0.01$) highest egg crude fiber content was confirmed for KK (1.63 ± 0.11), higher for CH (1.44 ± 0.07) breeds, whereas the lowest egg crude fiber content was observed for HC (1.36 ± 0.05), C (1.33 ± 0.05), L (1.29 ± 0.01) and H (1.25 ± 0.05) breed eggs.

3.3. Egg Quality Parameters of KK, HC, CH, C, H, and L Chickens

External and Internal Egg Quality

The results of external and internal egg quality attributes of different chickens are shown in **Table 4**. Egg weight was significantly highest ($P \leq 0.001$) for KK (52.72 ± 0.55), and higher for CH (47.58 ± 0.25) compared to other hens studied. In contrast, the egg weight of HC (46.24 ± 0.20), C (45.97 ± 0.42), and H (45.56 ± 0.19) did not differ significantly. Moreover, egg weight was found significantly lower for L (40.57 ± 0.54) as compared to other hens for that trait. Egg weight was significantly highest for WLH (63.39 ± 0.57), higher for Naked Neck (52.15 ± 0.57 and Aseel Peshawari (51.50 ± 0.77), high for Fayoumi (50.51 ± 0.57), intermediate for RIR (49.07 ± 0.60), lower for Aseel Lakha (47.63 ± 0.59) and Aseel

Table 4. Egg quality traits of KK, HC, CH, C, H, and L chickens.

Category	**Genotype(G)**						**P-value**
	KK	**HC**	**C**	**CH**	**H**	**L**	
Egg quality	**Mean ± SE**						**G**
External							
EW	52.72 ± 0.55^{a}	46.24 ± 0.20^{c}	45.97 ± 0.42^{c}	47.58 ± 0.25^{b}	45.56 ± 0.19^{c}	40.57 ± 0.54^{d}	***
EL	53.29 ± 0.35^{a}	50.74 ± 0.36^{b}	50.54 ± 0.26^{cb}	51.05 ± 0.43^{b}	49.63 ± 0.37^{c}	47.57 ± 0.27^{d}	***
EB	40.62 ± 0.22^{a}	37.98 ± 30^{cb}	37.61 ± 0.24^{c}	38.50 ± 0.34^{b}	37.25 ± 0.30^{c}	36.07 ± 0.21^{d}	***
ESI	76.22 ± 0.63	74.85 ± 0.83	74.42 ± 0.92	75.41 ± 0.79	75.06 ± 0.81	75.83 ± 0.78	Ns
EST	0.36 ± 0.01^{a}	0.34 ± 0.04^{b}	0.33 ± 0.01^{c}	0.34 ± 0.05^{b}	0.33 ± 0.02^{c}	0.30 ± 0.06^{d}	***
ESW	7.05 ± 0.14^{a}	5.21 ± 0.10^{b}	5.09 ± 0.06^{cb}	5.25 ± 0.08^{b}	4.83 ± 0.09^{c}	4.19 ± 0.13^{d}	***
SWR	13.37 ± 0.18^{a}	11.23 ± 0.10^{cb}	11.04 ± 0.15^{cb}	11.28 ± 0.23^{b}	10.59 ± 0.16^{dc}	10.31 ± 0.22^{d}	***
Internal							
AW	28.99 ± 0.31^{a}	27.07 ± 0.35^{b}	25.82 ± 0.30^{c}	27.43 ± 0.33^{b}	25.03 ± 0.21^{c}	22.81 ± 0.38^{d}	***
AWR	55.00 ± 0.23^{c}	59.33 ± 0.69^{a}	56.16 ± 0.31^{cb}	56.90 ± 0.68^{b}	54.94 ± 0.37^{c}	56.09 ± 0.38^{cb}	***
AHT	6.03 ± 0.07^{a}	5.48 ± 0.06^{b}	5.46 ± 0.07^{b}	5.51 ± 0.05^{b}	5.34 ± 0.04^{b}	4.82 ± 0.04^{c}	***
YW	16.68 ± 0.21^{a}	13.96 ± 0.31^{d}	15.06 ± 0.20^{c}	14.90 ± 0.19^{c}	15.70 ± 0.22^{b}	13.57 ± 0.17^{d}	***
YWR	31.66 ± 0.38^{c}	30.18 ± 0.63^{dc}	32.80 ± 0.55^{c}	31.33 ± 0.47^{d}	34.47 ± 0.49^{a}	33.49 ± 0.41^{b}	***
YHT	16.12 ± 0.09^{a}	15.19 ± 0.20^{b}	15.21 ± 0.28^{b}	15.24 ± 0.14^{b}	14.91 ± 0.15^{b}	13.72 ± 0.22^{c}	***
YWT	40.20 ± 0.27^{a}	39.88 ± 0.19^{ba}	39.17 ± 0.28^{cb}	40.06 ± 0.18^{a}	38.93 ± 0.30^{c}	37.55 ± 0.34^{d}	***
YI	40.13 ± 0.38^{a}	38.09 ± 0.67^{b}	38.83 ± 0.74^{ba}	38.04 ± 0.42^{cb}	38.30 ± 0.49^{b}	36.54 ± 0.50^{c}	**
YC	4.53 ± 0.13^{c}	5.07 ± 0.18^{cb}	4.93 ± 0.21^{cb}	5.13 ± 0.19^{ba}	5.27 ± 0.20^{ba}	5.67 ± 0.18^{a}	**
YAR	0.57 ± 0.01^{b}	0.51 ± 0.02^{c}	0.58 ± 0.01^{b}	0.54 ± 0.03^{c}	0.63 ± 0.01^{a}	0.59 ± 0.02^{b}	***
HU	79.43 ± 0.78^{a}	78.01 ± 0.76^{ba}	77.98 ± 0.25^{ba}	77.69 ± 1.09^{ba}	77.27 ± 0.26^{cb}	75.57 ± 0.37^{c}	**

^{abcd}EW = Egg weight (g), EL = Egg length (mm), EB = Egg width (mm), ESI = Egg shape index, EST = Egg shell thickness (mm), ESW = Egg shell weight (g), SWR = Egg shell weight ratio (%), AW = Albumen weight (g), AWR = Albumen weight ratio (%), AHT = Albumen height (mm), YW = Yolk weight(g), YWR = Yolk weight ratio (%),YHT = Yolk height (mm), YWT = Yolk width (mm), YI = Yolk index, YC = Yolk color (1 - 15), YAR = Yolk albumen ratio, HU = Haugh unit, Ns = P > 0.05, *** = P < 0.001, ** = P < 0.01, SE = Standard error, Cosmopolitan (C), Improved Horro (H), Cosmopolitan ♂ * ♀ Improved Horro (CH), Improved Horro ♂ * ♀ Cosmopolitan (HC), indigenous (L) and Koekkoek (KK) Hens' eggs.

Mianwali (47.50 ± 0.59) breeds [5]. However, the egg weight of the Rhode Island Red breed was significantly lower (57.60 ± 0.76) than the egg weight (60.96 ± 0.56) of Oravka breeds [50]. Likewise, a significantly lower egg weight was observed in smooth x naked neck (37.80) hen eggs than in Frizzle (45.04) hen eggs while the rest hens' eggs were demonstrated significantly intermediate as cited by [51]. Results also noted that positive and significant correlations were observed between body weight and egg weight of Fayoumi breed (r = 0.333) and Dokki (r = 0.323) and the bodyweight of Fayoumi was heavier (1.359 ± 0.053) than that of Dokki (1.302 ± 0.051) breeds [52]. In agreement with the study, egg weight was significantly and positively influenced by the body weight of laying hens and egg size which, is mostly associated with the body size of the laying hens and might be due to egg weight observed to have the highly heritable trait to be varied across and within breeds [53] [54]. In this study, the egg length was found significantly lowest ($P \leq 0.001$) for L (47.57 ± 0.27), Lower for H (49.63 ± 0.37), intermediate for C (50.54 ± 0.26), higher for CH (50.74 ± 0.36) and HC (51.05 ± 0.43) but the highest egg length noted for KK (53.29 ± 0.35) eggs from breeds. The egg length of Vanaraja was noted significantly ($P < 0.01$) higher (54.50 ± 0.76) than C1 (53.80), C2 cross (53.60), and Gramapriya (54.00) across genotypes [21]. Besides, study results confirmed that Boris Brown egg length was found significantly ($P < 0.01$) higher (57.90 ± 2.20) followed by Nagoya (55.30 ± 2.70) and Yakido (45.00 ± 2.80) breeds [53]. Also, results demonstrated that the Naked neck egg length was significantly ($P < 0.01$) higher (52.70 ± 0.02) than Normal (53.10 ± 0.03), but the Dwarf (50.50 ± 0.03) strain has the lowest egg length of the three strains [25]. In contrast, reports revealed that egg length was insignificant ($P > 0.05$) between Aseel (51.60 ± 0.04) and Kadaknath (51.30 ± 0.03) breeds [55]. As a result, egg length might be affected due to differences across breeds [56] [57] [58], which is consistent with the study.

Egg width was observed significantly highest ($P \leq 0.001$) for KK (40.62 ± 0.22), higher for CH (38.50 ± 0.34), high for HC (37.98 ± 30), intermediate for C (37.61 ± 0.24), and H (37.25 ± 0.30) while the lowest was illustrated for L (36.07 ± 0.21) in the breeds studied. The egg width of Dominant Red Barred was significantly ($P < 0.05$) highest (43.90) followed by Dominant Sussex (42.30), Lohmann Brown Classic (42.00), and Lohmann Dual (41.70), and Koekoek (41.30) egg width breeds [27]. The highest ($P < 0.05$) egg width of the egg was noted in Sindhi (41.29 ± 0.27), higher in Mushki (40.80 ± 0.33), Intermediate in Peshawari (40.18 ± 0.37) followed by the lowest egg width from Lakha hens (39.36 ± 0.47) as reported by [41]. The highest ($P < 0.001$) egg width of the egg was noted in Rhode Island Red (44.30 ± 0.13), higher in Cob500 (42.20 ± 0.08), Intermediate in Sonali (41.20 ± 0.12) followed by the lowest egg width of eggs of Fayoumi (37.20 ± 0.23) and (37.10 ± 0.15) breeds [59]. However, significantly ($P < 0.001$) highest proportions of egg shape indices were found in Brown (79.43 ± 4.39) followed by White (76.12 ± 5.92) and Black (75.85 ± 4.38) breeds [60].

Eggshell thickness was observed significantly lowest ($P \leq 0.001$) for L (0.30 ± 0.06), intermediate for C (0.33 ± 0.01), and H (0.33 ± 0.02), and high for HC (0.34 ± 0.04) and CH (0.34 ± 0.05), while found significantly highest for KK (0.36 ± 0.01) for the trait studied. A significantly ($P < 0.001$) thickest eggshell was observed in Blacked strain (0.36 ± 0.04) followed by Brown (0.34 ± 0.03), by contrast, the thinnest eggshell was illustrated in Spotted (0.32 ± 0.02) strains [61]. In addition, a significantly ($P < 0.001$) thickest eggshell was recorded for the Normal strain (0.41 ± 0.007), whereas the eggshell thickness in both Dwarf (0.38 ± 0.007) and Naked neck (0.38^{b} ± 0.006) strains were noted insignificantly ($P > 0.05$) differed [25]. However, a significantly ($P < 0.001$) thinnest eggshell was calculated for the Yakido breed eggs (0.37 ± 0.03) than Nagoya (0.44 ± 0.03), and Boris Brown (0.45 ± 0.03) breeds [53]. The variations in shell thickness might be attributed to the significant influence of sunlight in the formation of vitamin D3, resulting in the differences in the level of calcium absorption, retention, and mobilization of the trait between and within breeds [41]. Also, significant differences in shell thickness might attribute to variations of resistance to breakage, contamination, bio-economic characteristics, and hatchability across breeds [19] [23] [58]. Furthermore, the variation in eggshell thickness might be greatly affected by selection and epigenetics across and within genotypes [22]. Shell weight was reported significantly ($P \leq 0.001$) heaviest for KK (7.05 ± 0.14), heavier for CH (5.25 ± 0.08) and HC (5.21 ± 0.10), intermediate for C (5.09 ± 0.06), heavy for H (4.83 ± 0.09) whereas the lightest shell weight was observed in the L (4.19 ± 0.13) breeds. The shell weight was significantly ($P < 0.01$) higher for Rhode Island Red (9.10 ± 2.23), intermediated for Sonali (7.90 ± 1.29) whereas, the lowest shell weight was illustrated for Cob500 (6.80 ± 1.23), Indigenous (6.41 ± 1.97) and Fayoumi (6.14 ± 2.02) breed eggs [59]. However, the shell weight of the egg was insignificantly ($P > 0.05$) affected among Black (5.24 ± 0.03), Brown (5.19 ± 0.48), and Spotted (5.16 ± 0.46) strain eggs [61]. The shell weight ratio was significantly ($P \leq 0.001$) highest for KK (13.37 ± 0.18), higher for CH (11.28 ± 0.23), intermediate for HC (11.23 ± 0.10), and C (11.04 ± 0.15) whereas, the lowest shell weight was observed in the L (10.31 ± 0.22) breeds. Shell weight ratio was significantly ($P < 0.001$) revealed between Rhode Island Red (10.83 ± 0.16) and Oravka (9.98 ± 0.10) breeds [50]. The differences in shell weight ratio are attributed to the variation in the levels of calcium deposition, shell weight, and egg weight across breeds [62].

The albumen weight was observed significantly highest ($P \leq 0.001$) for KK (28.99 ± 0.31), higher for CH (27.43 ± 0.33) and HC (27.07 ± 0.35), intermediate for C (25.82 ± 0.30) and H (25.03 ± 0.21) breed eggs, whereas significantly lowest albumen weight was implicated for L (22.81 ± 0.38) breed eggs. A significantly ($P < 0.05$) higher albumen weight was observed in the White Leghorn eggs than in Fayoumi eggs (38.85 ± 3.38 vs. 22.06 ± 2.54) [4]. In contrast, a significantly ($P < 0.05$) lower albumen weight was recorded in Normal Feathered (17.61) than in naked neck (20.53) breeds [48]. In addition, albumen weight was significantly ($P < 0.001$) lowest in Yakido (24.7 ± 1.5) breed**s**, intermediate in Nagoya (32.6 ± 2.4) breed**s**, whereas significantly highest albumen weight was recorded for Boris Brown (36.1 ± 3.5) breeds [53]. The variation in the balance of thick albumen was broadly affected by genetic backgrounds and egg weight constitutions [63]. Also, variation in the intensity of lay and age at sexual maturity of breeds might be associated with the albumen quality of eggs from breeds [64]. The HC breed had a significantly ($P \leq 0.001$) highest albumen weight ratio (59.33 ± 0.69) egg, higher for CH (56.90 ± 0.68) hen egg, intermediate for C (56.16 ± 0.31) hen egg, and L (56.09 ± 0.38) hen egg, whereas the lowest was obtained for KK (55.00 ± 0.23), and H (54.94 ± 0.37) hen eggs from breeds. A significantly ($P < 0.001$) higher albumen weight ratio was noted in Black (62.44 ± 0.34), and Brown (62.16 ± 0.35) hens than in Spotted (59.45 ± 0.51) breeds [61]. However, the Aseel breed was significantly highest in an albumen weight ratio (46.37 ± 0.78), lower in Fayoumi (52.04 ± 0.74), and NN (51.32 ± 1.59), low in WPR (54.45 ± 1.10), but albumen weight ratio was noted significantly lowest in RIR eggs (59.58 ± 1.19) from breeds [32]. There was a significantly ($P \leq 0.001$) highest albumen height for KK (6.03 ± 0.07), intermediate for CH (5.51 ± 0.05), HC (5.48 ± 0.06), C (5.46 ± 0.07), and H (5.34 ± 0.04), whereas significantly lowest albumen height was observed for L (4.82 ± 0.04) breed. The eggs from the Isa Brown hen had significantly ($P < 0.001$) higher albumen height than eggs from the Mos hen (7.14 vs. 5.89) [42]. However, a significantly ($P < 0.001$) lowest albumen height was recorded for Gramapriya (5.61) eggs, lower for Vanaraja (6.12), and C2 cross (6.12) eggs, but the highest albumen height (6.49) was obtained for eggs from C1 cross [21]. A significantly ($P \leq 0.001$) heaviest yolk weight was observed for KK (16.68 ± 0.21), heavier for H (15.70 ± 0.22), Intermediate for C (15.06 ± 0.20), and CH (14.90 ± 0.19) breeds, whereas yolk weight was recorded significantly lightest for HC (13.96 ± 0.31) and L (13.57 ± 0.17) breeds. In the same line, a significantly ($P < 0.001$) highest yolk weight was exhibited for the Black breed (15.28 ± 0.83) than Spotted (14.77 ± 0.11) and Brown (14.70 ± 0.98) breeds [61]. Additionally, a significantly ($P < 0.001$) higher yolk weight has been recorded in Boris Brown eggs (17.5 ± 1.6) than in Nagoya (15.9 ± 0.9) and Yakido (15.0 ± 1.5) breeds [53]. A significantly highest yolk weight ratio was observed for H (34.47 ± 0.49), higher for L (33.49 ± 0.41), intermediate for C (32.80 ± 0.55), KK (31.66 ± 0.38), whereas significantly ($P < 0.001$) lowest yolk weight ratio was recorded for CH (31.33 ± 0.47) and HC (30.18 ± 0.63) eggs from breeds. The Brown strain egg had a significantly ($P < 0.001$) lower yolk weight ratio (26.54 ± 0.23) than the eggs from the Spotted (27.44 ± 0.27), and Black (27.75 ± 0.17) hens [61]. However, the yolk weight ratio was significantly ($P < 0.01$) higher for control (29.56 ± 0.24), IWI (29.17 ± 0.23), and IWK (29.15 ± 0.25) breeds than that of IWH (28.28 ± 0.24) breed [65].

KK had significantly ($P \leq 0.001$) highest yolk height (16.12 ± 0.09), intermediate yolk height for CH (15.24 ± 0.14), HC (15.19 ± 0.20), C (15.21 ± 0.28), and H (14.91 ± 0.15), however, L eggs exhibited the lowest yolk height (13.72 ± 0.22). A significantly higher yolk height was recorded in Aseel (15.30 ± 0.35) breed eggs than in Kadaknath (14.26 ± 0.35) breeds [55]. Moreover, PK (15.3), and HR (14.8) had significantly ($P < 0.01$) higher yolk height than TL (13.8) and GF (13.4) eggs from the hens [62]. However, a significantly ($P < 0.05$) lower yolk height was observed in the Naked neck strain (1.67 ± 0.03), with a higher yolk height for the Normal strain (1.74 ± 0.04), whereas a significantly highest yolk height (1.82 ± 0.05) was recorded for the Dwarf strain, in cm [25]. Furthermore, a significantly lower yolk height was stated in New Hampshire (17.25 ± 1.12), Plymouth Rock Buff (17.12 ± 1.14), Sussex Light (17.02 ± 1.11), Rhode Island Red (16.73 ± 1.07) breeds than that Oravka (17.97 ± 1.09) breeds [64]. The difference in yolk height is attributed to the variation in egg-laying hen breeds and egg sizes [63]. The yolk width was significantly (P ≤ 0.001) lowest for L (37.55 ± 0.34), low for H (38.93 ± 0.30), high for C (39.17 ± 0.28), and higher for HC (39.88 ± 0.19), whereas the highest was assigned for CH (40.06 ± 0.18), and KK (40.20 ± 0.27) eggs from breeds. The eggs of the Aseel breed had significantly higher yolk width than Kadaknath eggs (40.10 ± 0.26 vs. 38.97 ± 0.27) [55]. However, yolk width was significantly lower in DR (39.23 ± 0.239) than in GP (40.03 ± 0.257), VR (40.12 ± 0.239), and RC (40.48 ± 0.268) eggs from breeds [55]. The yolk width might be influenced by genotypes [63] and differ due to the variation in egg-laying hen and egg sizes, too [62]. A significantly (P ≤ 0.01) highest yolk index was recorded for KK (40.13 ± 0.38) breed eggs, higher for C (38.83 ± 0.74) breed eggs, high for H (38.30 ± 0.49), and HC (38.09 ± 0.67) breed eggs, intermediate for CH (38.04 ± 0.42) breed eggs, however, the lowest was revealed for L (36.54 ± 0.50) breeds. The yolk index of the egg from the Rhode Island Red breed was significantly (P < 0.05) lower than an egg from the Oravka breed (40.31 ± 1.00 vs. 42.14 ± 0.50) [50]. Yolk indices might be varied due to differences in breed [21]. There was a significantly (P ≤ 0.001) highest yolk color for L (5.67 ± 0.18), higher yolk color for H (5.27 ± 0.20), and HC (5.13 ± 0.19), intermediate yolk color for CH (5.07 ± 0.18), and C (4.93 ± 0.21), but the lowest yolk color was scored for KK (4.53 ± 0.13). Significantly (P < 0.001) higher yolk color was scored for Hybrid (13.33) than eggs from that of Preta (9.55), Amarela (9.08), Branca (8.82), and Pedres (8.64) breeds [24]. The RIR breed showed a significantly (P ≤ 0.01) darker yolk color than the Oravka (11.10 ± 0.20 vs.10.60 ± 0.09) [50]. LB strain had a significantly (P < 0.01) lowest yolk color (5.26), lower for LW strain (5.41), and low for LB strain (5.70), but the highest yolk color (6.15) was observed for Cross strain [56]. The yolk color was affected by the breed [21] and the yolk color of egg-laying breeds might have also some degree of heritability [32] [56]. A significantly highest yolk albumen ratio was observed in H (0.63 ± 0.01), higher in L (0.59 ± 0.02), C (0.58 ± 0.01), and KK (0.57 ± 0.01) breed eggs, whereas the lowest yolk albumen ratio was obtained for CH (0.54 ± 0.03) and HC (0.51 ± 0.02) breeds. The PK breed had significantly (P < 0.01) lowest yolk albumen ratio (0.48), lower for TL (0.52), and low for HR (0.55), but GF (0.59) was the highest yolk albumen ratio of eggs from breeds [62]. A significantly (P < 0.01) highest Haugh unit score was observed for KK (79.43 ± 0.78), intermediate for HC (78.01 ± 0.76), CH (77.98 ± 0.25), and C (77.69 ± 1.09) breeds, lower for H (77.27 ± 0.26) breed, whereas the lowest Haugh unit was observed for L (75.57 ± 0.37) breed. A significantly (P < 0.05) higher Haugh unit was calculated in eggs of Aseel than in Kadaknath (82.88 ± 0.95 vs. 79.82 ± 1.09) [55]. Additionally, there has been a significantly (P < 0.05) highest Haugh unit score in the Dwarf breed (88.88 ± 1.83) than in Naked neck (81.05 ± 1.38), and in Normal feathered (78.44 ± 1.71) eggs from breeds [25]. A significantly (P < 0.05) lowest Haugh unit score was observed in Sindhi (66.65 ± 2.16) breed, lower in Mushki (72.40 ± 2.02) and Peshawari (73.88 ± 1.74) breeds, whereas the significantly highest Haugh unit score was recorded in Lakha (39.36 ± 0.47) breed eggs [41]. Similarly, a significantly lowest Haugh unit score was revealed in the White line (88.46 ± 0.30), lower in the Dark Brown line (88.89 ± 0.28), whereas the highest Haugh unit score was obtained in the Light Brown line (89.67 ± 0.36) eggs [57]. A Haugh unit score of 72 and above of a given hen egg can be classified as an AA grade/fresh [66]. The variation in the Haugh unit score is attributed to the difference in the viscosity of thick albumen in hen breeds [50] [67]. The difference in the Haugh unit score is attributed to the variation in albumen height and egg weight of observed hen breeds [32] [41], in which the Haugh unit score is considered a measure of the quality of the thick albumen of eggs from breeds [44].

The correlation coefficient (r) between the external quality and nutritional composition of an egg is presented in **Table 5**. The egg weight was positively and significantly correlated with egg length ($r = 0.987$; $P < 0.001$), egg width ($r = 0.984$; $P < 0.001$), shell thickness ($r = 0.961$; $P < 0.01$), shell weight ($r = 0.964$; $P < 0.01$), shell weight ratio ($r = 0.908$; $P < 0.05$), moisture ($r = 0.895$; $P < 0.05$), crude fat ($r = 0.788$; $P < 0.05$), crude ash ($r = 0.930$; $P < 0.05$), crude fiber ($r = 0.863$; $P < 0.05$), whereas the egg weight was negatively and significantly correlated with crude protein ($r = -0.951$; $P < 0.01$) of eggs from breeds. The egg weight had a positive and significant correlation with egg length ($r = 0.943$; $P < 0.05$), egg width ($r = 0.857$; $P < 0.05$), and shell weight ($r = 0.347$; $P < 0.01$) from breeds [61]. A study of previous works corroborated that egg weight had a positive

Table 5. Pearson's correlation (r) among external egg quality and nutritional composition of KK, HC, CH, C, H, and L chickens.

Parameter	EW	EL	EB	ESI	EST	ESW	SWR	Mo	CP	Fat	Ash	CF
EW	1.000	0.987***	0.984***	0.287^{Ns}	0.961**	0.964**	0.908*	0.895*	−0.951**	0.788*	0.930*	0.863*
EL		1.000	0.976***	0.199^{Ns}	0.935**	0.949**	0.900*	0.941**	−0.975***	0.894*	0.950*	0.859*
EB			1.000	0.407^{Ns}	0.921**	0.984***	0.949**	0.861*	−0.960**	0.953**	0.971**	0.937**
ESI				1.000	0.223^{Ns}	0.442^{Ns}	0.492^{Ns}	-0.070^{Ns}	-0.234^{Ns}	0.542^{Ns}	0.425^{Ns}	0.615^{Ns}
EST					1.000	0.895*	0.821*	0.831*	−0.852*	0.779^{Ns}	0.8215^{Ns}	0.739^{Ns}
ESW						1.000	0.986***	0.796^{Ns}	−0.914*	0.929**	0.942*	0.929**
SWR							1.000	0.723^{Ns}	−0.868*	0.908*	0.921*	0.936**
Mo								1.000	−0.951**	0.905*	0.877^{Ns}	0.718^{Ns}
CP									1.000	−0.938**	−0.979**	−0.897*
Fat										1.000	0.995***	0.979***
Ash											1.000	0.970**
CF												1.000

EW = Egg weight (g), E = Egg length (mm), EB = Egg width (mm), ESI = Egg shape index, EST = Shell thickness (mm), ESW = Shell weight (g), SWR = Shell weight ratio (%), Mo = Moisture, CP = Crude Protein, Fat = Crude Fat, Ash = Crude Ash, CF = Crude Fiber, Ns = $P > 0.05$, *** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, Cosmopolitan (C), Improved Horro (H), Cosmopolitan ♂ * ♀ Improved Horro (CH), Improved Horro ♂ * ♀ Cosmopolitan (HC), indigenous (L) and Koekkoek (KK) hens' eggs.

and significant correlation with shell thickness (r = 0.152; P < 0.001) of eggs from breeds [23]. Conversely, the egg weight had a negative and significant correlation with the shell weight ratio of eggs (r = −0.446; P < 0.001) from breeds [68]. Possibly, a significant difference in egg weight from breeds had also significantly affected the shell weight ratio of eggs from breeds [69]. The Egg from the breed with heavier egg weight had significantly higher moisture content than the eggs from relatively lighter breeds [4]. The egg from the breed with heavier egg weight had significantly higher ash content than the eggs from a comparatively lighter breed [70]. The eggs from the breed with heavier egg weight had significantly higher fat content than the eggs from a lighter breed [45]. The Eggs of breeds with varied egg weights had significantly affected the ash content of breeds [42]. The eggs from the Mos had significantly higher crude protein (12.31 vs. 11.66) than the Isa Brown breed egg, whereas the Isa Brown breed egg had significantly higher moisture (77.40 vs. 74.35) than that of the Mos breed egg, respectively [58]. Probably, the egg length had a positive and significant correlation with egg width (r = 0.976; P < 0.001), sell thickness (r = 0.935; P < 0.01), shell weight (r = 0.949; P < 0.01), shell weight ratio (r = 0.900; P < 0.05), Mo (r = 0.941; P < 0.01), Fat (r = 0.894; P < 0.05), Ash (r = 0.950; P < 0.05), and CF (r = 0.859; P < 0.01), whereas egg length had a negative correlation with crude protein (r = −0.975; P < 0.001). As can be observed, the egg width had a positive significant correlation with shell thickness (r = 0.921; P < 0.01), shell weight (r = 0.984; P < 0.001), shell weight ratio (r = 0.949; P < 0.01), Mo (r = 0.861; P < 0.05), Fat (r = 0.953; P < 0.01), Ash (r = 0.971; P < 0.01), and CF (r = 0.937; P < 0.01), but egg width had strong and negative correlation with crude protein (r = -0.960; P < 0.01). Shell thickness was positively and significantly correlated with shell weight (r = 0.895; P < 0.05), shell weight ratio (r = 0.821; P < 0.05), and Mo (r = 0.831; P < 0.05), whereas shell thickness was found significantly and negatively correlated with crude protein (r = -0.852; P < 0.05). Crude protein from eggs of laying hens had significantly and negatively correlated with crude fat (r = -0.938; P < 0.01), crude ash (r = −0.979; P < 0.01), and crude fiber (r = −0.897; P < 0.05). Interestingly, the protein content of eggs from breeds had a negative significant correlation with most of the external egg quality and other proximate composition traits of eggs from breeds. Similarly, the indirect relationships of the crude protein content of eggs from breeds to both traits correlated might be due to variation of breeds [70]. The crude fat had significantly and positively correlated with crude ash (r = 0.995; P < 0.001), and crude fiber (r = 0.979; P < 0.001). The crude ash content from breeds had a positive significant correlation with crude fiber (r = 0.970; P < 0.01. The direct association of crude ash content and fat accumulation might be attributed to the physiological response of eggs from breeds drunk saline drinking water [49].

The correlation coefficient (r) between egg internal quality and egg weight of different chickens is presented in **Table 6**. The egg weight had a positive and significant correlation with albumen weight (P < 0.001), albumen height (P <

Table 6. Pearson's correlation (r) between internal egg quality and egg weight of KK, HC, CH, C, H, and L chickens.

Parameter	AW	AWR	AHT	YW	YWR	YHT	YWT	YI	YC	YAR	HU	EW
AW	1.000											
AWR	0.355**	1.000										
AHT	0.672***	−0.062^{Ns}	1.000									
YW	0.469***	−0.334**	0.546***	1.000								
YWR	−0.466***	−0.331**	−0.201^{Ns}	0.473***	1.000							
YHT	0.554***	−0.177^{Ns}	0.618***	0.441***	−0.255*	1.000						
YWT	0.850***	0.349**	0.483***	0.366**	−0.417***	0.456***	1.000					
YI	0.144^{Ns}	−0.387**	0.420***	0.286**	−0.053^{Ns}	0.866***	−0.049^{Ns}	1.000				
YC	−0.389***	0.050^{Ns}	−0.341**	−0.308**	0.147^{Ns}	−0.315**	−0.277**	−0.198^{Ns}	1.000			
YAR	−0.514***	−0.655***	−0.103^{Ns}	0.508***	0.914***	−0.119^{Ns}	−0.474***	0.129^{Ns}	0.098^{Ns}	1.000		
HU	0.307**	−0.062^{Ns}	0.430***	0.308**	−0.065^{Ns}	0.311**	0.262*	0.201^{Ns}	−0.304**	0.002^{Ns}	1.000	
EW	0.891***	−0.086^{Ns}	0.749***	0.657***	−0.351**	680***	0.739***	0.345**	−0.446***	−0.235*	0.377**	1.000

AW = Albumen weight (g), AWR = Albumen weight ratio (%), AHT = Albumen height (mm), YW = Yolk weight(g), YWR = Yolk weight ratio (%), YHT = Yolk height (mm), YWT = Yolk width (mm), YI = Yolk Index, YC = Yolk color (1 - 15), YAR = Yolk Albumen ratio, EW = Egg weight (g), HU = Haugh unit, Ns = P > 0.05, *** = P < 0.001, ** = P < 0.01, * = P < 0.05, Cosmopolitan (C), Improved Horro (H), Cosmopolitan ♂ * ♀ Improved Horro (CH), Improved Horro ♂ * ♀ Cosmopolitan (HC), indigenous (L) and Koekkoek (KK) Hens' eggs

0.001), yolk weight (P < 0.001), yolk height (P < 0.001), yolk width (P < 0.001), yolk index (P < 0.01), and haugh unit(P < 0.01) (0.377 < r < 0.891). The egg weight had a positive and significant (P < 0.05) correlation with albumen weight (r = 0.66), albumen height (r = 0.79), yolk weight (r = 0.69), yolk height (r = 0.79), yolk width (r = 0.64), yolk index (r = 0.30), and Haugh unit (r = 0.48) of eggs from naked neck and normal feathered chickens [3]. The positive and strong correlation of egg weight with the above traits is suggesting that there is an integrated and concomitant nature in each egg trait from egg-laying breeds and have genetic implications [61] [65] [71]. However, egg weight implicated a significant and negative correlation with yolk color (P < 0.001), yolk weight ratio (P < 0.01), and yolk albumen ratio (P < 0.05) (−0.446 < r < −0.235). Likewise, yolk color had a negative and significant correlation with egg weight (r = −0.322; P < 0.05), albumen weight (r = −0.365; P < 0.05), and albumen ratio (r = −0.345; P < 0.05) [72]. The eggs from traditional breeds showed significantly higher yolk color than eggs from commercial breeds (8.6 vs. 7.3) [73]. The Oravka breed eggs had a significantly higher egg weight (60.96 ± 0.56), and lower yolk color (10.60 ± 0.09) than the egg weight (57.60 ± 0.76), and yolk color (11.10 ± 0.20) of eggs from the RIR [50]. The egg weight of breeds had a negative and significant correlation with the yolk weight ratio of breeds (r = -0.21; P < 0.01) [67]. The Eggs from breeds with significantly (P < 0.01) highest egg weight showed significantly lowest yolk albumen ratio: GF > PK) [62]. The significant difference might be due to variation in breed, epigenetic, dilution, and pleiotropic effects of genes from breeds [74] [75] [76]. The Haugh unit of eggs from breeds had positive and significant correlations with albumen weight ($r = 0.307$; $P < 0.01$), albumen height ($r = 0.430$; $P < 0.001$), yolk weight ($r = 0.308$; $P < 0.01$), yolk height ($r = 0.311$; $P < 0.01$), and yolk weight ($r = 0.262$; $P < 0.05$), whereas Haugh unit of eggs from breeds had a negative and significant correlation with yolk color ($r = -0.304$; $P < 0.01$). The Haugh unit had a positive and significant correlation with albumen weight ($r = 0.270$; $P < 0.01$), albumen height ($r = 0.971$; $P < 0.01$), yolk weight ($r = 0.265$; $P < 0.01$), yolk height ($r = 0.479$; $P < 0.01$), and yolk width ($r = 0.099$; $P < 0.05$) [61]. Accordingly, the Haugh unit had also a negative and significant correlation with the yolk color (-0.119; $P < 0.01$) from breeds [77]. Some studies reported that the difference in the association of the Haugh unit score with yolk color pigmentation level might be possibly due to the variation in egg weight, albumen height, liver function, breed, epigenetic, and pleiotropic genes [23] [50] [62] [74]. The Haugh unit was influenced by the albumen height and egg weight of eggs from breeds in line with the current finding [63]. Furthermore, the yolk albumen ratio was positively and significantly correlated with yolk weight ($r = 0.508$; $P < 0.001$), and yolk weight ratio ($r = 0.914$; $P < 0.001$), however, it was negatively and significantly correlated with albumen weight ($r = -0.514$; $P < 0.001$), albumen weight ratio ($r = -0.655$; $P < 0.001$), and yolk width of eggs ($r = -0.474$; $P < 0.001$) from breeds. Consistently, yolk color of eggs from breeds had negative and significant correlation with albumen weight ($r = -0.389$; $P < 0.001$), albumen height ($r = -0.341$; $P < 0.01$), yolk weight ($r = -0.308$; $P < 0.01$), yolk height ($r = -0.315$; $P < 0.01$), and yolk width ($r = -0.277$; $P < 0.01$). This difference might be due to the variation in the size of eggs and hen breeds [57] [59] [77]. The yolk index from breeds of eggs had a positive and significant association with albumen height ($r = 0.420$; $P < 0.001$), yolk weight ($r = 0.286$; $P < 0.01$), and yolk height ($r = 0.866$; $P < 0.001$), however; it had also revealed a negative and significant association with the albumen weight ratio of eggs from breeds ($r = -0.387$; $P < 0.01$). Like our results, the direct positive correlation between yolk index with albumen height showed that there could be balanced osmotic migration from albumen to yolk via the vitelline membrane from breeds [78]. The yolk index significantly differed by breed/genotype [19] [76]. The yolk width had a positive and significant association with albumen weight ($r = 0.850$; $P < 0.001$), albumen weight ratio ($r = 0.349$; $P < 0.01$), albumen height ($r = 0.483$; $P < 0.001$), yolk weight ($r = 0.366$; $P < 0.01$), yolk height ($r = 0.456$; $P < 0.001$), but yolk width of eggs from hens had a negative and significant association with the yolk weight ratio of eggs from breeds ($r = -0.417$; $P < 0.001$). The current result is in line that yolk width might be varied due to differences in breeds and egg sizes [22] [62]. The yolk height has a positive and significant relationship with albumen weight ($r = 0.554$; $P < 0.001$), albumen height ($r = 0.618$; $P < 0.001$), and yolk weight ($r = 0.441$; $P < 0.001$), whereas yolk height has a negative and significant relationship with yolk weight ratio (r = −0.255; P < 0.05. The yolk weight ratio was positively and significantly correlated with yolk weight (r = 0.473; P < 0.001), it was, however, negatively, and significantly correlated with albumen weight (r = −0.466; P < 0.001) and albumen weight ratio (r = −0.331; P < 0.01). Further, the yolk weight was positively and significantly correlated with albumen weight (r = 0.469; P < 0.001) and albumen height (r = 0.546; P < 0.001), on the contrary, yolk weight had a negative and significant correlation with albumen weight ratio (r = −0.334; P < 0.01). Albumen height of eggs from hens had a positive and significant relationship with albumen weight (r = 0.672; P < 0.001). The albumen weight ratio of eggs from breeds had a positive and significant correlation with albumen weight (r = 0.355; P < 0.01). In the same line, the albumen weight ratio had a positive and significant correlation with the albumen weight (r = 0.57; P < 0.01) from breeds [67]. The difference in the correlation between external and internal egg quality traits is attributed to the variety of breeds and leads to the use of traits as important parameters for hen and egg-related improvement studies [3] [19] [50] [62] [78].

4. Conclusion and Recommendation

In the current study, it was noted that sensory characteristics, nutritional composition, and egg quality significantly varied among hens. There had been a significant effect in flavor, appearance, and acceptance of scrambled and boiled eggs of hens. The moisture, crude protein, crude fat, crude ash, and crude fiber of eggs were significantly affected among chickens. External and internal egg equality significantly varied among hens. Egg weight had significantly and positively correlated with nutritional composition and egg quality except for yolk color, yolk weight ratio, yolk albumen ratio, and crude protein across hens. Genetic manipulation could have compromised sensory characteristics, nutritional composition, and quality of hens' eggs. The chickens with lower egg weight notified higher crude protein and lower crude fat, and are better preferred by panelists. The variation in genotypes could affect sensory characteristics, nutritional composition, and egg quality across hens' eggs. It might also provide clues to future breeding programs and dietary studies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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