



Effect of Production System and Age on Egg Quality Parameters: A Case of Niğde Province Çamardı District, Turkey

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ABSTRACT

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This study compared egg quality parameters in layers under free-range system with prefabricated pens and backyard while emphasizing hen age. A total of 300 eggs collected from prefabricated pens and backyard farming families in the Çamardı District of Niğde Province were used as study materials. The assessed external and internal egg quality characteristics included egg weight, shape index, shell thickness, shell breaking strength, albumen index, Haugh unit, yolk index, and yolk colour. The effect of production system on albumen index, Haugh unit, and yolk colour score was found statistically significant. There was a significant effect of age on shape index, shell thickness, shell breaking strength, albumen index, Haugh Unit, yolk index, and yolk colour score. The effect of interaction between age and production system was statistically significant for shape index, shell thickness, yolk index, Haugh Unit, and yolk colour score. It was determined that the egg's meat and blood spots percentages from the free-range and backyard systems were 10.6% and 15.3%, respectively. It was concluded that while eggs produced from free-range system are superior in terms of egg weight, shape index, and Haugh unit those obtained from backyard hens are higher in eggshell thickness, eggshell breaking strength, and egg yolk colour.

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Introduction

The demand for chicken products such as eggs has increased in parallel with change in socio-economic and demographic profiles, rapid and increased urbanization, accelerated population growth in cities, and industrialization (Henchion et al., 2017). It is established that in the 20th century the above factors influenced the transition from traditional to industrial chicken production systems. The traditional production system composed of the backyard (5-10 birds), and free-roaming chickens to meet the egg and meat needs of families.

In several developed countries, accelerated transitions in the layer chicken industry including hen intensification and genetic improvement of laying hens were observed after the 1960s (Tainika and Şekeroğlu, 2020). Today, commercial laying hen hybrids have achieved an annual egg yield of 310-330 eggs with feed conversion rates of 2.1-2.3 (Hocking, 2015). During this period, the developed battery cage production system for laying hens has played an important role in meeting the need for eggs. Meanwhile, this

led to the emergence of behavioral and welfare problems especially metabolic disorders and skeletal disorders, and the intensive laying hen production system has been criticized for failing to meet the basic needs of chickens (Şekeroğlu and Diktaş, 2012). Battery cage production system is highlighted for insufficient space and restricted movement that compromises hen's ability to express natural behaviors (Widowski et al., 2016; Scrinis et al., 2017; Rohlf et al., 2019).

In a survey, Żakowska-Biemans and Tekień (2017) identified that eggs produced from free-range had a higher comparable significance to consumers than organic eggs although the latter is majorly known for high hen welfare standards. Furthermore, as a factor affecting egg quality, hen welfare has become an increasingly important marketing strategy (Widmar et al., 2020; Tufarelli et al., 2018). Due to these market reactions powered by increased consumer perception in the world, alternative chicken production systems including free-range that prioritize hen welfare have

been enhanced (Tufarelli et al., 2018; Ochs et al., 2018). The free-range system is characterized by ease of movement, enough space, outdoor access that enables the hens to perform their natural behaviors in addition to exposure to sunlight, and free diets like small insects and forage. Production systems highly influence egg quality and performance characteristics (Englmaierová et al., 2014; Lordelo et al., 2017; Philippe et al., 2020), and consumers are interested in the price and nutritional value of poultry products, as well as quality criteria such as hygiene, food safety, colour, aroma, flavour, etc (Rondoni et al., 2020).. Samiullah et al. (2017) determined that the eggs from the free-range system were superior to other systems for shell weight, albumen index, and Haugh unit, and an earlier study by Lewko and Gornowicz (2011) reported the highest shell weight and thickness for free-range eggs. On the contrary, Yenice et al. (2016) identified lower albumen index and Haugh unit values in free-range eggs compared to cage eggs. In one study, yolk colour values were higher in free-range eggs as opposed to other systems (Samiullah et al. 2014). Significant values of albumen quality and yolk index of free-range eggs compared with litter system were found by Mohammed et al. (2013). Sarıca et al. (2021) stated that farmers perceive eggs from a backyard chicken are superior in terms of quality and health compared with other commercial systems. However, studies regarding the egg quality in backyard chickens are rare yet the system is still common among the rural communities due to the above perceptions. Therefore, the current study compared egg quality in free-range and backyard systems while considering the effect of flock age.

Material and Method

The study was conducted between December 2019 and April 2020 using eggs obtained from 10 enterprises (5 from each of free-range egg and backyard chicken enterprises) in Çukurbağ, Demirkazık, and Orhaniye villages of Çamardı district of Niğde Province, Turkey. The province is located in the Central Anatolia region of Turkey at an altitude of 1299 m (37°58'00"N 34°40'45"E). The study did not involve animal rearing but a brief description of the two production systems is given below.

Animal Material and Husbandry

The animal material comprised of ATA-K-S layer hybrids (Turkish developed breed) in the free-range system, while in backyard system, hens were local brown layers Within farming families. Under the free-range system, 250 hens were housed in prefabricated pens of 32 m² (4 × 8 m), including an outdoor area of 1000 m². There were 2 lines of 7-meter nipple drinkers, 36 nest boxes, and 5 feeders each with a capacity of 12 kg. The hen pens had 2 windows providing ventilation and lighting. Water and feeds were provided without restriction and access to outdoor area was adjusted according to daily weather conditions and day length, and the stocking density was 4 hens/m².

The number of chickens in backyard system, the pens, and outdoor areas varied with the possibilities and did not have a specific standard (uncontrolled environmental village conditions).

In both systems, hens were fed layer feeds containing 88% KM, 16% crude protein, and 2750 kcal/kg metabolic energy produced by various commercial trademarks. Besides, there was feed supplementation with forage and wheat grains during summer and winter, respectively. Furthermore, natural and artificial lighting was used depending on the day length however, a specific lighting program was not applied.

The hens under free-range system were obtained from a commercial business and until the 17th-week, vaccination against Marek, Newcastle, Gumbaro, and Infectious Bronchitis was completed. In backyard system, farmers obtained chicks themselves from fertilized eggs using an incubator, and no effective health protection program was implemented.

Egg Samples

The eggs used in the study were produced from hens between 25-30, 33-38, and 40-46 weeks of age with an interval of 8 weeks. A total of 10 eggs were randomly selected from each of the 5 enterprises in both systems, and this process was repeated for each age group. At the end of the trial, a total of 300 eggs were used (150 eggs from each production system).

Egg Quality Analyses

The eggs were collected from the enterprises and brought to the Egg Quality Analysis Laboratory of the Department of Animal Production and Technologies of Niğde Ömer Halisdemir University. The eggs were stored at room temperature for 24 hours before the analysis. Apart from the albumen height and yolk colour score that were automatically detected with an egg analyzer device (Orka food technology), all the other egg quality traits were determined according to Şekeroğlu et al. (2014). Briefly, after 24 hours of storage, egg weight was measured with a precision balance (sensitivity of 0.01 g). Egg width and length were taken with a digital calliper to find the shape index (SI) values with the formula below.

$$SI = (\text{Egg width} / \text{Egg length}) \times 100.$$

Eggshell breaking strength was measured with an egg force reader branded measuring device (Orka food and technology).

The inner membranes of the shell samples taken from the blunt, middle, and pointed part of the broken eggs were removed, and the shell thickness was determined with a 1/100 mm sensitive micrometer.

Then, albumen and yolk width and length, and yolk diameter were measured on the glass table with a digital caliper (± 0.001 mm). The values obtained from above were used to calculate albumen and yolk index (AI and YI, respectively), and Haugh unit with the formulas below;

$$AI = (\text{AH (mm)} / (\text{AL (mm)} + \text{AW (mm)}) / 2) \times 100$$

$$YI = \text{YH (mm)} / (\text{YD (mm)}) \times 100$$

$$\text{Haugh Unit} = 100 \text{ Log} (\text{AH} + 7.57 - 1.7\text{G}^{0.37}),$$

AH : Albumen height (mm),
 AL : Albumen length
 AW : Albumen width
 YH : Yolk height
 YD : Yolk diameter
 G : Egg weight (g).

Statistical Analysis

All data was shown as the mean \pm standard error (SE) and analysed by the General Linear Model procedure of SPSS software version 18. The data of egg quality characteristics was checked for normality and homogeneity of variance, of which data in line with the normal distribution was analysed by 1-way analysis of variance (ANOVA). Duncan's multiple range test was used to analyse mean difference among groups when significance ($P < 0.05$) was identified. All values with ($P < 0.05$) were considered statistically significant. The identified egg's meat and blood spots were calculated as percentages.

Results

Effect of Production System

The effect of production system on external egg quality parameters (egg weight, shape index, shell thickness, and eggshell breaking strength), and internal egg quality characteristics (albumen index, Haugh unit, and yolk colour score) was statistically significant ($P < 0.01$). Egg's meat and blood spots percentages were 10.6% and 15.3% for free-range and backyard laying hen production systems, respectively.

Effect of Age

Age effect on external egg quality features (shape index, shell thickness, eggshell breaking strength) and internal egg quality parameters (Albumen index, Haugh Unit, yolk index, yolk colour score) was found significant ($P < 0.01$; $P < 0.05$). The effect of interaction between age and production system was significant for shape index, shell thickness, Haugh Unit, yolk index, and yolk colour score ($P < 0.01$; $P < 0.05$). All the findings of the study are shown in Table 1 and Table 2.

Discussion

This study evaluated the differences in egg quality parameters between free-range and backyard hens at different ages. Although the effect of age on egg weight was not significant in this study, we determined that egg weight increased with advancing hen's age in the free-range system. This is similar to a study by Bari et al. (2020) when the authors investigated the effect of early rearing enrichments on some egg quality parameters in free-range layers. Furthermore, various studies have reported that there was an increase in egg weight with advancing hen's age (Yılmaz Dikmen et al., 2017; Vlčková et al., 2019; Kraus et al., 2021). Also, we identified that eggs from free-range layers were heavier than those in the backyard system. The similar result was identified by Yenice et al. (2016). It is thought that free-range system may be less affected by environmental factors since it is more controlled than the backyard in addition to the genotypes used. Several authors have reported that environment and laying hen genotype are some of the factors that impact egg weight (Van Den Brand et al., 2004; Sirri et al., 2018; Zita et al., 2018).

In the present study, there was a significant effect of production system, age, and the interaction of age and production system on shape index. In agreement, several studies observed that there is a significant effect of production system on shape index (Englmaierová et al., 2014; Zita et al., 2018). In contrast to our study, Molnar et al. (2016) identified that there was no effect of hen's age on shape index. Also, Hanusova et al. (2015) determined that there was no significant difference in shape index between eggs from two dual-purpose breeds. However, Yenice et al. (2016) found that there was a greater shape index in eggs from free-range hens than those in the backyard. We assumed that the shape index could as well be affected by the breeds used in the various production systems thus, a possible reason for the observed significant effect of production system in the current study. Sokołowicz et al. (2019) reported that there was a significant effect of hen genotype on shape index. The significant effect of age on shape index could be associated with increasing egg weight and a statistically significant positive correlation between egg weight and shape index has been reported by Duman et al. (2016).

We found that the average eggshell thickness was higher in eggs from the backyard system. Furthermore, the overall effect of production system and the interaction of age with the production system on eggshell thickness was significant. The statistical significance of age and production system interaction was linked to the hen age. In agreement, Petek et al. (2009) observed that there was a significant difference in eggshell thickness for production systems and age but on the contrary, they found that there was no significant effect of interaction between age and production system on eggshell thickness. Also, Van Den Brand et al. (2004) identified that there was no significant difference in shell thickness between production systems, and in eggs from the outdoor system, shell thickness increased or was constant with increasing hen's age. The above authors recommended that an eggshell – housing system be used as a bio-indicator for laying hen management. Yenice et al. (2016) determined that the shell thickness of free-range eggs was higher compared with backyard system, and these conflicts with the present study. We argue that different genotypes were used in the production systems in the present study thus, the effect of production system on eggshell thickness could be associated with breed effect. A study by Hanusova et al. (2015) found that there was a significant difference in eggshell thickness between breeds.

We observed that eggshell breaking strength was significantly affected by the production system and age though higher in eggs from the backyard system. Furthermore, the effect of interaction between age and production system was not significant for eggshell breaking strength. Petek et al. (2009) found a similar effect of age and age-housing system interaction for eggshell strength however, the effect of housing system was in disagreement with the present study. Similarly, Bari et al. (2020) identified that there was no significant effect of production system on eggshell breaking strength which is contrary to the current study.

Table 1. The effect of production system on internal and external quality characteristics

Trait	Production system		SEM	P-value
	Free-range	Backyard		
Egg weight (g)	62.94 ^a	58.33 ^b	0.46	0.01
Shape index (%)	74.86 ^a	76.42 ^b	0.27	0.01
EST (mm)	0.34 ^a	0.37 ^b	0.02	0.01
EBS (kg/cm ²)	3.40 ^a	4.10 ^b	0.07	0.01
Albumen index (%)	5.95 ^a	4.93 ^b	0.16	0.01
Haugh Unit	62.81 ^a	57.73 ^b	1.20	0.01
Yolk index (%)	47.49	44.92	0.89	0.05
Yolk colour score (%)	9.64 ^a	10.19 ^b	0.12	0.01
MBS (%)	12.95	14.30		

^{a,b} Values within a row with different superscripts differ significantly at P<0.05. Abbreviations: SEM, standard error of the mean; EST, eggshell thickness; EBS, eggshell breaking strength; MBS, meat and blood spots

Table 2. The effect of production system, age and age production system interaction on internal and external quality characteristics

Trait	A (week)	PS		Mean	SEM	P (A)	P (A × PS)
		FR	VP				
Egg weight (g)	25-30	62.89	57.24	60.06			
	33-38	61.60	59.18	60.39	1.82	0.05	0.05
	40-46	64.33	58.56	61.44			
Shape index (%)	25-30	73.94	75.46	74.70 ^a			
	33-38	75.03	77.80	76.42 ^b	0.33	0.01	0.05
	40-46	75.62	75.99	75.80 ^b			
EST (mm)	25-30	0.34	0.36	0.35 ^a			
	33-38	0.32	0.38	0.35 ^a	0.07	0.05	0.05
	40-46	0.36	0.38	0.37 ^b			
EBS (kg/cm ²)	25-30	3.44	3.90	3.67 ^a			
	33-38	2.97	3.97	3.47 ^a	0.09	0.01	0.05
	40-46	3.78	4.44	4.11 ^b			
Albumen index (%)	25-30	4.47	5.52	4.99 ^a			
	33-38	7.24	3.33	5.28 ^a	0.19	0.01	0.05
	40-46	6.13	5.95	6.04 ^b			
Haugh Unit	25-30	51.58	61.86	56.92 ^a			
	33-38	71.72	46.82	59.27 ^a	1.46	0.01	0.01
	40-46	64.74	64.52	64.63 ^b			
Yolk index (%)	25-30	48.08	48.04	48.06 ^b			
	33-38	47.68	39.42	43.55 ^a	0.97	0.05	0.05
	40-46	46.72	47.30	47.01 ^b			
YCS (%)	25-30	10.22	10.60	10.41 ^c			
	33-38	8.92	10.04	9.41 ^a	0.15	0.01	0.05
	40-46	9.94	9.92	9.93 ^b			

^{a,b,c} Values within a row with different superscripts differ significantly at P<0.05. Abbreviations: EST, eggshell thickness; YCS, yolk colour score; EBS, eggshell breaking strength; A, age; PS, production system; FR, free-range; VP, backyard; SEM, standard error of the mean; A × PS, age - production system interaction

However, they determined that there was no significant effect of age and production system interaction on eggshell breaking strength which is in line with our study. Yenice et al. (2016) stated that free-range eggs had a higher eggshell breaking strength compared with backyard in contrast to the current study. Similarly, Kraus et al. (2021) determined a significant effect of production system, age, and age - production system interaction for eggshell thickness.

According to Lewko and Gornowicz (2011), the main determinant of table egg quality is albumen quality (albumen height and Haugh Unit) and is mainly affected by age besides the production system. In the present study, the effect of production system, age, and age - production system interaction on albumen index and Haugh unit was significant determined as significant. Also, as age advanced, albumen index and Haugh unit decreased. In

agreement, Doyon et al. (1985) found that flock age was inversely proportional to albumen height and Haugh unit. We found the highest Haugh unit (64.74) in eggs from both systems, and this is much lower compared with what was reported in several studies (Yenice et al., 2016; Sirri et al., 2018; Zita et al., 2018; Hanusova et al., 2015). Furthermore, in agreement with the present study, several studies found that there was a significant effect of production system on Haugh unit (Lewko and Gornowicz, 2011; Englmaierová et al., 2014; Samiullah et al., 2014). In the current study, the albumen index in free-range and backyard system eggs was 5.95 and 4.93%, respectively versus 5.68 and 6.05% (Yenice et al., 2016). These values are lower than those reported in various studies (Hanusova et al., 2015; Kraus et al., 2021).

Yolk quality is determined by the yolk index. In the current study, were identified that there was a statistically significant and no significant difference of production system, age, and age-production system interaction, respectively in the yolk index. In parallel with the study, Petek et al. (2009) determined that the effect of production system on yolk index was not significant however, Englmaierova et al. (2014) and Mohammed et al. (2013) stated that the effect of production system was significant for the yolk index.

Egg yolk colour is one of the important egg interior quality characteristics, and the demand for yolk colour may vary according to the consumer's preferences. The effect of production system on yolk colour score was statistically significant, and the scores for eggs obtained from the backyard system were found higher as opposed to free-range. In agreement, Yenice et al. (2016) reported that the yolk colour score for eggs from the backyard system is superior compared with free-range. This supported the consumer's perception that eggs produced from backyard hens have darker coloured yolks compared with the commercial systems. However, Sarica et al. (2021) reported that the consumer's belief that the level of the darker yolk colour is the same both in village type and the free-range system was not true. The effect of age and age-production system interaction for yolk colour was found significant. Petek et al. (2009) identified a similar effect of age for yolk colour but the effect of age-production interaction on yolk colour was in contrast with the present study. Meat and blood spots in egg content are significant internal quality criterion that affects consumer demand. We observed that meat and blood spot values in the eggs obtained in the free-range were lower than in the village system. Genetic factors were thought to be the main causes of high egg meat and blood spots in the village laying hen system though the spots are known to be influenced by other factors such as stress during ovulation, uncontrolled nutrition, vitamin deficiency, and infectious diseases. Furthermore, Nalbandov and Card (1944) stated that blood and meat spots in eggs increase in summer, and these spots in eggs are influenced by laying hen housing and floor conditions.

In conclusion, for external quality properties, while the free-range system outperforms in shape index and egg weight, the backyard system is dominant in shell thickness, shell strength, and yolk colour score. The free-range system is superior in all the internal egg quality characteristics excluding yolk colour. Thus, the system is better for desired quality parameters such as albumen index (a measure of freshness), Haugh Unit, yolk index, and meat and blood spots percentages.

Age and production system caused increasing and decreasing effects in some egg quality features. It is thought that this may be due to changing climatic and housing conditions, nutritional variations, vitamin and mineral deficiencies, infectious diseases, and genetic differences in animals used.

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Conflict of Interest

The authors declare they have no conflict of interest.

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