

Yumurta Kalite Parametreleri Üzerine Farklı Yetiştirme Sistemleri ve Mevsimin Etkisi

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Araştırma Makalesi

Makale Tarihi:

Geliş tarihi: 31.12.2024

Kabul tarihi: 22.08.2025

Online Yayınlanma: 13.01.2026

Anahtar Kelimeler:

Farklı yetiştirme sistemleri

Aile tipi

Kafes sistemi

Free range sistemi

Yumurta dış ve iç kalitesi

ÖZ

Bu araştırma, farklı yetiştirme sistemlerinde (kafes sistemi, aile tipi ve serbest gezen sistem) üretilen tavuk yumurtalarının dış ve iç kalite parametreleri üzerindeki mevsimsel (ilkbahar, yaz, sonbahar ve kış) etkisini incelemek amacıyla yapılmıştır. Çalışmada farklı yetiştirme sistemlerinden her bir mevsimde 50'şer adet olmak üzere toplam 600 adet yumurta toplanmıştır. Yumurta örneklerinin dış kalite parametreleri üzerine mevsimin etkisi incelendiğinde; kış mevsiminde kırılma mukavemeti, kabuk kalınlığı, sarı yüksekliği ve sarı indeksi önemli bulunmuştur ($p<0,05$). İlkbahar mevsiminde sarı çapı üzerinde mevsimin etkisi önemli olmuştur ($p<0,05$). Yaz mevsiminde ise şekil indeksi, sarı renk, Haugh birimi, kırılma mukavemeti, kabuk kalınlığı, kabuk ağırlığı ve sarı çapı önemli sonuçlar vermiştir ($p<0,05$). Sonbahar mevsiminde şekil indeksi, yumurta ağırlığı, sarı renk, kabuk kalınlığı, kabuk ağırlığı, sarı yüksekliği ve sarı çapında mevsimin etkisi önemli ($p<0,05$) bulunurken, incelenen diğer dış kalite parametreleri üzerinde istatistiksel açıdan anlamlı bir etki gözlenmemiştir ($p>0,05$). Yumurta dış kalite parametrelerine göre, serbest gezen sistemin şekil indeksi (%) ve yumurta ağırlığında, kafes sisteminin ise sarı renkte en iyi sonuçları sağladığı belirlenmiştir ($p<0,05$). Mevsimin yumurta iç kalitesi üzerine etkisi, yumurta sarısında kışın protein, ilkbahar ve yazın ise β -karoten değerleri üzerinde istatistiksel açıdan anlamlı bulunurken ($p<0,05$) benzer şekilde yumurta akında, sonbahar mevsiminde pH değerleri, kış ve yaz dönemlerinde ise protein değerleri istatistiksel açıdan önemli bulunmuştur ($p<0,05$). Yumurtanın tümü incelendiğinde ise kış döneminde kuru madde ve kül değerleri önemli sonuçlar vermiş olup, diğer incelenen iç kalite parametreleri üzerinde mevsimin istatistiksel açıdan anlamlı bir etkisi gözlenmemiştir ($p>0,05$). Yumurta iç kalite parametreleri açısından, yumurta sarısında protein ve β -karoten ile tüm yumurtada kuru madde ve kül oranı için serbest gezen sistem; yumurta akında ise pH ve protein değerleri açısından aile ve kafes işletmelerinde en iyi sonuçlar elde edilmiştir. Sonuç olarak, yumurta dış kalite özelliklerinde serbest gezen ve kafes sistemlerinin, iç kalite özelliklerinde ise serbest gezen yetiştirme sisteminin en iyi performansı sergilediği belirlenmiştir.

Effect of Different Breeding Systems and Season on Egg Quality Parameters

Research Article

Article History:

Received: 31.12.2024

Accepted: 22.08.2025

Published online: 13.01.2026

ABSTRACT

This study was conducted to examine the seasonal (spring, summer, autumn, and winter) effect on the external and internal quality parameters of chicken eggs produced in different rearing systems (cage system, family-type system, and free-range system). A total of 600 egg samples were collected, with 50 eggs from

Keywords:

Different rearing systems
Cage system
Family type
Free range system
Egg external and internal quality

each rearing system in each season. When the effect of the season on the external quality parameters of egg samples was examined, it was found that the breaking strength, shell thickness, yellow height and yellow index were important during the winter season ($p < 0.05$). The effect of the season on the yellow diameter in the spring season was significant ($p < 0.05$). In summer, shape index, yellow color, Haugh unit, breaking strength, shell thickness, shell weight and yellow diameter gave important results ($p < 0.05$). While the effect of the season on the shape index, egg weight, yellow color, shell thickness, shell weight, yellow height and yellow diameter in the autumn season was significant ($p < 0.05$), no statistically significant effect was observed on other external quality parameters studied ($p > 0.05$). According to the external egg quality parameters, it was determined that the free-roaming system provided the best results in terms of shape index (%) and egg weight, while the cage system provided the best results in yellow color ($p < 0.05$). The effect of the season on the internal quality of eggs was statistically significant on protein in winter in egg yolk, and β -carotene values in spring and summer ($p < 0.05$), while pH values in autumn season and protein values in winter and summer periods were found to be statistically significant in egg white ($p < 0.05$). When all the eggs were examined, dry matter and ash values gave important results during the winter period, and there was no statistically significant effect of the season on the other internal quality parameters studied ($p > 0.05$). In terms of egg internal quality parameters, a free-floating system for protein and β -carotene in the yolk and the dry matter and ash ratio in the whole egg; and the best results were obtained in family and cage enterprises in terms of pH and protein values in the egg white. Consequently, it has been determined that free-range and cage systems exhibited the best performance in external egg quality characteristics, while the free-range rearing system showed the best performance in internal quality characteristics.

To Cite: Tekdemir OA., Tekce E. Effect of Different Breeding Systems and Season on Egg Quality Parameters. Araştırılması. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2026; 9(1): 307-321.

1. Introduction

The egg is an important source of protein that offers the opportunity to meet the rapidly increasing food demand, as well as a nutrient of strategic and critical importance for the livestock sector. Eggs are a rich source of antioxidants containing macronutrients (Calcium (Ca), Magnesium (Mg), Phosphorus (P), and Potassium (K)) and micronutrients (Iron (Fe), Zinc (Zn), Manganese (Mn), Iodine (I), and selenium (Se)), valuable vitamins (A, D, E, K, and B group (B1, B2, B3, B5, B6, B9, and B12)) (Mathieu-Huart et al., 2014; Wang et al., 2018; Réhault-Godbert et al., 2019; Anonymous, 2024). Eggs are one of the easiest, cheapest, and most preferred protein-rich animal source products for humans. In addition, they are a valuable nutrient in terms of protein digestibility (98%) and biological value (94%) (Sparks, 2006; Altan, 2015; Yenice et al., 2016; Türker and Alkan, 2019). Egg production and quality (internal and external) parameters are influenced by various factors such as age, rearing environment and system, and nutrition (Özbey and Esen, 2007; Jones et al., 2012; Radu-Rusu et al., 2014; Steinfeldt and Hammershøj, 2015; Yenice et al., 2016; Tavares et al., 2018).

Many farming systems, such as conventional, organic, free-range, and enriched cage systems, are applied in egg farming. The most preferred system worldwide is the conventional system (89.7%) (Anonymous, 2016). The main reason for the preference of this system is that the cost of egg production is low due to the high amount of output throughout the year, and the product is accessible to the public (Pavlovski et al., 2010; Rakonjac et al., 2014; Rakonjac et al., 2018). However, it is stated that this

system negatively affects chickens' natural behavior and animal welfare (Campbell et al., 2016; Damaziak et al., 2021). For this reason, depending on consumer demands and increasing expectations, producers have started to apply different production systems to obtain higher yields, meet the increasing demand, and improve standards related to animal health and welfare (Moura et al., 2006; Tavares et al., 2018). Despite intensive research on egg quality, extensive studies focusing on the simultaneous and interactive effects of different breeding systems and seasonal changes on the internal and external quality parameters of eggs are limited in the literature. In this context, our current study aims to examine the seasonal (spring, summer, autumn and winter) effects on the internal and external quality parameters of eggs obtained from various breeding systems (cage, family type and free movement).

2. Materials ve Method

The study was carried out on egg samples obtained from hen egg farms with different rearing systems (cage system, family type, and free-range system) in the central district of Bayburt province in 2021 and 2022 (40.16°N, 39.89°E). To evaluate the effect of seasonal variation on the quality parameters of egg samples, a total of 600 eggs — 50 eggs from each rearing system (cage system, family type, and free-range system) — were collected and examined in four different seasonal periods (spring, summer, autumn, and winter). To minimize confounding factors in the study, the same breed of chickens (Tinted breed), which were obtained from the same hatchery at the same time, were selected.

Feed material and water

Hens in different rearing systems always had access to water. Free-range and cage system hens were fed with second-period layer feed (crude protein: 17%, crude fat: 4.2%, crude fiber: 4.4%, crude ash: 12.2%, lysine: 0.91%, methionine: 0.38%, Ca: 3.9%, P: 0.46%, Na: 0.14%) supplied by a private feed company.

Collection of egg samples

Within the scope of this research, a total of 600 egg samples were collected from producers in Bayburt province, comprising 50 eggs from each of the three different rearing systems (cage system, family type, and free-range system) across four distinct seasons (spring, summer, autumn, and winter). Following their collection, the eggs were transported to the Bayburt University Food Engineering Laboratory. Prior to analysis, the eggs were kept at room temperature for 1 day. Subsequently, their internal and external quality parameters were analyzed.

Egg external and internal quality analysis

In the study, the external quality analysis of the eggs collected in different seasonal periods and different rearing systems was carried out in the laboratory of Atatürk University Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Diseases, using a digital egg tester (Nabel DET6000 digital egg tester, JAPAN). In this context, the egg's external quality (Shape Index (%), Egg Weight (g),

White height (mm), Yolk color, Haugh Unit, Colour, Breaking Strength (kg/f), Shell Thickness (mm), Yolk Height (mm), Yolk Diameter (mm), Yolk Index (%) and Shell Weight (g) data were analyzed. Egg internal quality analyses (% dry matter, % ash, % fat, pH, protein (%), and β -carotene ($\mu\text{g/g}$)) were performed at Bayburt University Faculty of Engineering, Food Engineering Laboratory.

In this study, the external quality analysis of eggs collected across different seasonal periods and from various rearing systems was conducted at the Atatürk University Faculty of Veterinary Medicine, Department of Animal Nutrition and Nutritional Diseases Laboratory, using a Nabel DET6000 digital egg tester (JAPAN). The analyzed external quality parameters included: Shape Index (%), Egg Weight (g), Albumen Height (mm), Yolk color, Haugh Unit, Colour, Breaking Strength (kg/f), Shell Thickness (mm), Yolk Height (mm), Yolk Diameter (mm), Yolk Index (%) and Shell Weight (g). Concurrently, internal egg quality analyses, specifically for dry matter (%), ash (%), fat (%), pH, protein (%), and β -carotene ($\mu\text{g/g}$), were performed at the Bayburt University Faculty of Engineering, Food Engineering Laboratory.

Statistical Analysis

SPSS 22 software was used to analyze the obtained data. A general linear model was employed to determine the effect of season (winter, spring, summer, autumn) and rearing systems (cage system, family type, and free-range system) on the quality parameters of the collected egg samples. Duncan's multiple range test was applied to determine the statistical differences among the means. Statistical significance was set at $p < 0.05$ and $p < 0.01$ levels.

3. Results and Discussion

Evaluation of Egg External Quality Data

Breeding systems are considered a non-genetic factor influencing the quality and quantity of the products obtained and as well as animal welfare (Campbell et al., 2019; Wei et al., 2019; Abo Ghanima et al., 2020). Furthermore, egg quality is influenced by various factors such as age, physiological conditions, composition of the feed used, and internal and external characteristics of the egg (Bouvarel et al., 2011; Bain et al., 2016). The study conducted by Mugnai et al., (2009) stated that pasture was the primary basis of the seasonal effects of eggs obtained from different rearing systems (conventional, organic, and organic-plus). The study reported that organic-plus eggs exhibited superior quality concerning shell weight, yolk color, α -tocopherol, carotenoids, and with no significant differences in other parameters. Another study reported that the fatty acid concentration of egg yolk was influenced in the spring because organic-plus eggs consumed more green grasses from pasture. It was determined that polyunsaturated fatty acids (PUFA) n-6 concentration decreased, and the PUFA n-3 ratio increased in egg samples. Additionally, green grasses in the pasture were shown to effectively improve egg quality (Mugnai et al., 2014).

When the data obtained as a result of the analysis of the eggs collected in the study (Table 1) were evaluated, the best results ($p < 0.01$) were obtained in the eggs produced in the free-range system and family-type enterprises in shape index (%), free-range system and cage system in egg weight (g), cage system in yolk color, free-range and cage systems in breaking strength (kg/f) and shell thickness (mm) in the winter season. In the spring period, the best results ($p < 0.01$) were obtained for egg weight (g) and yolk height (mm) in the free-range and cage system, yolk color and yolk diameter (mm) in cage system, and breaking strength (kg/f) in family type production. In summer, the best results were obtained in egg weight (g), yolk height (mm), and yolk index (%) in the cage system, albumen height (mm) and Haugh unit in free-range and cage systems, shell thickness (mm) and breaking strength (kg/f) in free-range systems ($p < 0.01$). In autumn, the best results were obtained in egg weight (g) in the free-range system and breaking strength (kg/f) in egg samples from family-type enterprises (Table 2) ($p < 0.01$). When the literature data were analyzed, similar studies were not found. However, similar results were obtained when compared with the studies examining the periodical effects of rearing systems (Mugnai et al., 2009; Mugnai et al., 2014; Dong et al., 2017).

Egg quality is determined by the Haugh unit ($HU = 100 \log (h + 7.57) - (1.7w^{0.37})$), which was determined by Raymond Haugh in 1937 (Haugh, 1937). In the formula, h is the height, and w is the egg's weight. According to the formula, it is a key indicator in egg freshness and quality (Khaleel, 2019). Furthermore, egg freshness and quality are affected by the activity of lysozyme and other enzymes (e.g., ovalbumin and ovomucin) in the egg due to prolonged storage time (Roberts, 2004; Huang et al., 2012; Liu et al., 2020; Shan et al., 2020; Kowalska et al., 2021). As a result of the analysis of the data obtained from our study, it was determined that the best results were obtained in summer and autumn in shape index (%), yolk color, and shell weight (g), in summer in Haugh unit and breaking strength (kg/f), in autumn in egg weight, in winter and autumn in yolk height, in winter in the yolk index, in spring, summer and autumn in yolk diameter, in winter, summer and autumn in shell thickness. At the same time, there was no effect on other data (Tables 1 and 2) ($p < 0.05$).

When we evaluated the influence of different rearing systems on egg external quality in different seasonal periods in terms of rearing systems, the best results were obtained in shape index (%) and egg weight in free-range, yolk-color cage systems, while there was no effect on other data (Table 1 and 2) ($p < 0.05$). The literature information on the data obtained from our study was examined, but similar studies were not found. However, when compared with studies on different systems, it showed differences (Mugnai et al., 2009; Dong et al., 2017). The main reason for this is primarily attributed to differences in chicken breeds, differences in vegetation cover, and differences in feeding regimes.

Evaluation of Egg Internal Quality Data

There are various factors affecting egg internal quality. Among these factors, the nutrient content of feed, breed, age, and rearing systems are considered the most important (Cerolini et al., 2005; Rizzi et al., 2016; Minelli et al., 2007; Mugnai et al., 2009; Küçükyılmaz et al., 2012). Studies on the internal

quality of eggs in organic farming systems reported that albumin content and albumin protein percentages in egg samples from organic farming systems were lower than those from n-3-enriched systems (Lordelo et al., 2017). In a similar study, it was reported that free-range and organic eggs were higher in protein content (g/100 g) compared to conventional eggs but did not significantly affect other parameters (fatty acid profile (g/100 g) (9.4-10.1), Dry matter (g/100 g) (23.5-23.7) and whole egg pH (7.6) (Hidalgo et al., 2008). When the effect of season on egg internal quality was examined (summer, autumn, winter, and spring), it was reported that the season and rearing system did not affect the dry matter, protein, and lipid content of eggs from different rearing systems (closed system and organic egg systems) (Mugnai et al., 2009). When the data of our study were analyzed in the yolk part of the egg, the pH value was higher in the cage and family system in the summer period, protein content was higher in the free-range system in the winter period, and the β -carotene content ($\mu\text{g/g}$) in the eggs collected in the free-range system in the spring and summer periods was higher compared to other groups (Table 3), ($p < 0.05$). Regarding the white part of the egg, the pH value was higher in the cage system and family enterprises in the autumn period; protein values were higher in the family enterprises in the summer period, and protein values were also higher in the cage system and family enterprises in the winter period ($p < 0.05$). In terms of dry matter and ash (%), they were higher in free-range farms in the winter period (Table 4) ($p < 0.05$). The data obtained from our study were examined in conjunction with existing literature information, but similar studies were not found. However, when compared with studies on different systems, they showed consistency (Mugnai et al., 2009; Dong et al., 2017).

Table 1. Effect of season on egg external quality

	Shape Index (%)				Egg Weight (g)				White height (mm)				Yolk colour				Haugh unit			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Free Range	68.73±0.52 ^b	69.10 ^b	79.46 ^a	79.16 ^a	61.60±0.82 ^{cd}	62.93 ^{abc}	62.46 ^{bcd}	65.87 ^{bcd}	6.31±0.21 ^{abc}	5.69 ^c	6.65 ^{ab}	6.48 ^{abc}	9.63±0.29 ^{cd}	10.36 ^c	13.33 ^{ab}	13.32 ^{ab}	77.34±1.58 ^{abc}	72.21 ^c	80.04 ^{ab}	77.63 ^{abc}
Cage System	66.16±0.83 ^c	68.80 ^b	78.67 ^a	79.68 ^a	56.87±1.31 ^c	62.53 ^{bcd}	65.60 ^{ab}	62.01 ^{cd}	5.72±0.33 ^c	5.82 ^{bc}	6.94 ^a	5.97 ^{bc}	14.26±0.46 ^a	12.33 ^b	13.41 ^{ab}	13.84 ^a	74.82±2.51 ^{abc}	73.04 ^c	81.27 ^a	74.94 ^{abc}
Family Business	63.58±1.02 ^d	69.00 ^b	79.29 ^a	78.96 ^a	61.14±1.59 ^{cd}	59.48 ^{de}	59.19 ^{de}	64.02 ^{abc}	6.42±0.40 ^{abc}	6.16 ^{abc}	5.65 ^c	6.51 ^{abc}	7.80±0.56 ^e	9.03 ^d	13.95 ^a	13.96 ^a	78.50±3.08 ^{abc}	77.09 ^{abc}	73.94 ^{bc}	78.27 ^{abc}
Sem		0.59	0.66	0.64		0.92	1.03	1.01		0.23	0.26	0.25		0.32	0.36	0.36		1.78	1.99	1.95
P values of the groups																				
Season		0.00				0.00				0.05				0.00					0.04	
Cultivation systems (CS)			0.01				0.01				0.64				0.00					0.79
Season* CS			0.01				0.00				0.00				0.00					0.03
Impact of the season																				
Autumn		66.15±0.47 ^c				59.87±0.74 ^c				6.15±0.19				10.56±0.26 ^b					76.89±1.42 ^{ab}	
Winter		68.96±0.34 ^b				61.64±0.53 ^{bc}				5.89±0.13				10.57±0.19 ^b					74.11±1.03 ^b	
Spring		79.13±0.38 ^a				62.42±0.59 ^{ab}				6.42±0.15				13.56±0.21 ^a					78.42±1.15 ^a	
Summer		79.26±0.37 ^a				63.96±0.58 ^a				6.32±0.15				13.70±0.21 ^a					76.95±1.12 ^{ab}	
Impact of the breeding system																				
Free Range		74.11±0.30 ^a				63.22±0.47 ^a				6.28±0.12 ^a				11.66±0.17 ^b					76.80±0.92 ^a	
Cage System		73.32±0.34 ^b				61.75±0.54 ^{ab}				6.11±0.14 ^a				13.46±0.19 ^a					76.02±1.03 ^a	
Family Business		72.71±0.37 ^b				60.96±0.58 ^b				6.18±0.15 ^a				11.18±0.21 ^b					76.95±1.13 ^a	

There are statistically significant differences between the means indicated by different superscripts in a column (a,b,c) (p<0.05). 0,05 significance; 0,01 significance, NS: Not significant (p>0.05), SEM: Standard error of the mean (Cultivation systems (CS))

Table 2. Effect of season on egg external quality

	Crushing Strength (kg/f)				Shell Thickness (mm)				Yolk Height (mm)				Yolk Diameter (mm)				Yolk Index (%)				Shell weight (g)			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Free Range	4.68±0.18 ^{ab}	3.29 ^c	5.08 ^a	3.41 ^{cd}	0.36 ^a	0.33 ^b	0.37 ^a	0.35 ^{ab}	21.08±0.22 ^a	19.52 ^d	19.93 ^{bcd}	21.27 ^a	43.27±0.41	44.13	44.45	44.81	48.9	41.6	45	47.5	7.51±0.12 ^{bcd}	7.39 ^{bcd}	8.00 ^a	7.55 ^{abcd}
Cage System	5.17±0.28 ^a	3.41 ^{cd}	4.07 ^{ab}	4.12 ^{ab}	0.37 ^a	0.33 ^b	0.35 ^{ab}	0.37 ^a	20.48±0.34 ^{abc}	19.81 ^{cd}	20.72 ^{ab}	20.56 ^{abc}	41.88±0.65	45.16	44.72	44.26	49	43.9	46.4	46.9	7.31±0.18 ^{cde}	6.86 ^c	7.79 ^{abc}	7.84 ^{ab}
Family Business	3.45±0.34 ^{cd}	4.13 ^{ab}	4.33 ^b	4.37 ^b	0.30 ^c	0.35 ^{ab}	0.36 ^a	0.36 ^a	21.36±0.42 ^a	18.66 ^e	19.81 ^{cd}	20.58 ^{abc}	43.18±0.79	43.68	44.7	44.05	49.8	42.8	44.4	47.3	6.87±0.23 ^e	7.10 ^{de}	7.67 ^{abc}	7.70 ^{abc}
Sem		0.2	0.22	0.22	0.01	0.01	0.01	0.01		0.24	0.27	0.27		0.46	0.51	0.5		0.01				0.13	0.15	0.14
P values of the groups																								
Season		0.00				0.00				0.00				0.00				0.00				0.00		
Cultivation systems (CS)		0.75				0.13				0.18				0.77				0.51				0.03		
Season* CS		0.00				0.00				0.01				0.18				0.66				0.04		
Impact of the season																								
Autumn		4.43±0.16 ^a				0.35±0.01 ^a				20.97±0.19 ^a				42.78±0.37 ^b				49.3±0.01 ^a				7.23±0.10 ^d		
Winter		3.61±0.11 ^c				0.34±0.00 ^b				19.33±0.14 ^c				44.32±0.27 ^a				42.7±0.01 ^d				7.12±0.08 ^c		
Spring		4.49±0.13 ^a				0.36±0.01 ^a				20.15±0.16 ^b				44.62±0.29 ^a				45.3±0.01 ^c				7.82±0.08 ^a		
Summer		3.96±0.13 ^b				0.36±0.00 ^a				20.80±0.15 ^a				44.37±0.29 ^a				47.2±0.01 ^b				7.70±0.08 ^a		
Impact of the breeding system																								
Free Range		4.11±0.10 ^a				0.35±0.00 ^a				20.46±0.12 ^a				44.16±0.24				45.8±0.01				7.61±0.07 ^a		
Cage System		4.19±0.12 ^a				0.35±0.00 ^a				20.40±0.14 ^a				44.00±0.27				46.6±0.01				7.45±0.08 ^a		
Family Business		4.07±0.13 ^a				0.34±0.00 ^a				20.10±0.15 ^b				43.90±0.29				46.1±0.01				7.33±0.08 ^a		

There are statistically significant differences between the means indicated by different superscripts in a column (a,b,c) (p<0.05). 0,05 significance: 0,01 significance, NS: Not significant (p>0.05), SEM: Standard error of the mean (Cultivation systems (CS))

β -carotene, a precursor of vitamin A, is a carotenoid molecule commonly found in green leafy plants. Its inclusion in poultry nutrition is essential to support the immune system in poultry (Bayraktar et al., 2019). It has been stated that factors such as β -carotene, water-soluble vitamins, and plant diversity, especially in green pasture grasses, accumulate in eggs through this activity, particularly in chickens raised in organic and free-range systems in spring and summer (Mugnai et al., 2009). As a result of the interaction analysis, it was determined that the pH of the egg yolk was not affected by the season and rearing system ($p > 0.05$), and protein content was high in all periods except the winter period, depending on the season. The best results regarding rearing systems were obtained from eggs reared in a free-range system ($p < 0.05$). β -carotene ($\mu\text{g/g}$) was found to be the highest in the spring and autumn months, and the best results were obtained from free-range systems in terms of rearing systems ($p < 0.05$). Analysis of the white part of the egg revealed that pH was not significantly affected ($p > 0.05$), but the best results for protein were obtained in the winter season, depending on the season, and in the cage system and family farms in terms of breeding systems ($p < 0.05$). Evaluation of the whole egg (Table 4) indicated that while dry matter (%) was not significantly affected ($p > 0.05$), for ash (%), the best results by season were found in summer and the lowest results in the autumn season. The highest results in terms of breeding systems were found in free-range eggs, whereas the weakest results were found in family farms ($p < 0.05$). When the effect of the season was examined regarding the overall fat percentage of the egg, it was determined that the highest levels were observed in summer, and there was no effect in terms of breeding systems ($p > 0.05$). Literature relevant to the data obtained from our study was examined, but directly comparable studies were not found. However, compared with studies on different systems, they did not show consistency (Mugnai et al., 2009; Dong et al., 2017). The discrepancies among the studies are attributed to differences in chicken breeds, vegetation cover, and feeding regime.

Table 3. Seasonal effects on egg white and yolk internal quality parameters

WHITE PART OF THE EGG									YOLK PART OF THE EGG												
pH				Protein (%)				pH				Protein (%)				β- karoten (µg/g)					
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	
Free Range	8.78	8.95	8.85	9.05	9.46 ^{def}	10.47 ^{cde}	10.70 ^{bcd}	8.69 ^f	6.09	6.63	6.21	6.11	16.01 ^{ab}	15.93 ^{ab}	15.35 ^{ab}	15.32 ^{ab}	254.07 ^{ab}	171.75 ^{cde}	278.69 ^a	271.03 ^a	
Cage System	8.93	9.03	8.96	9.09	10.21 ^{cdef}	12.88 ^a	10.42 ^{cde}	9.07 ^{ef}	6.23	6.51	6.09	6.34	15.15 ^{ab}	10.16 ^c	16.31 ^a	15.52 ^{ab}	212.70 ^{bc}	95.85 ^f	197.92 ^{cd}	147.75 ^{de}	
Family Business	8.95	8.92	8.96	8.63	10.58 ^{bcd}	12.07 ^{ab}	9.96 ^{def}	11.73 ^{abc}	6.11	6.09	6.28	6.30	15.75 ^{ab}	9.11 ^c	15.35 ^{ab}	14.89 ^b	215.31 ^{bc}	137.70 ^{ef}	278.26 ^a	157.39 ^{de}	
Sem		0.09				0.48				0.15				0.40				16.07			
P values of the groups																					
Season		0.80				0.00				0.18				0.00				0.00			
Cultivation systems		0.16				0.00				0.65				0.00				0.00			
Season* CS		0.10				0.00				0.22				0.00				0.02			
Impact of the season																					
Autumn		8.891				10.088 ^b				6.147				15.639 ^a				227.364 ^a			
Winter		8.972				11.812 ^a				6.413				11.739 ^b				135.104 ^c			
Spring		8.928				10.363 ^b				6.197				15.676 ^a				251.631 ^a			
Summer		8.926				9.832 ^b				6.254				15.252 ^a				192.062 ^b			
Sem		0.06				0.277				0.09				0.233				9.28			
Impact of the breeding system																					
Free Range		8.912				9.833 ^b				6.264				15.658 ^a				243.891 ^a			
Cage System		9.006				10.648 ^a				6.296				14.292 ^b				163.560 ^c			
Family Business		8.87				11.089 ^a				6.198				13.780 ^b				197.170 ^b			
Sem		0.05				0.24				0.07				0.20				8.04			

There are statistically significant differences between the means indicated by different superscripts in a column (a,b,c) (p<0.05). 0,05 significance: 0,01 significance, NS: Not significant (p>0.05), SEM: Standard error of the mean (Cultivation systems (CS))

Table 4. Effect of season on internal quality parameters of eggs in general

WHOLE EGG												
	% Dry Matter				% Ash				% Oil			
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer
Free Range	22.27	27.58	29.42	26.31	0.79 ^{bcd}	1.00 ^a	0.81 ^{bcd}	0.96 ^a	8.04 ^b	11.79 ^{bc}	9.36 ^b	8.84 ^b
Cage System	22.12	25.36	24.46	29.43	0.75 ^{cd}	0.83 ^{bc}	0.82 ^{bc}	1.02 ^a	7.08 ^b	7.37	10.35 ^b	19.20 ^a
Family Business	22.02	26.87	22.78	25.99	0.73 ^d	0.86 ^b	0.80 ^{bcd}	0.96 ^a	6.53 ^b	10.98 ^{bc}	9.48 ^b	16.02 ^{ab}
Sem		2.27				0.03				1.70		
P values of the groups												
Season		0.05				0.00				0.00		
Cultivation systems		0.46				0.03				0.43		
Season* CS		0.61				0.00				0.01		
Impact of the season												
Autumn		22.14				0.759 ^d				7.226 ^b		
Winter		26.608				0.903 ^b				10.054 ^b		
Spring		26.224				0.812 ^c				9.735 ^b		
Summer		27.249				0.984 ^a				14.690 ^a		
Sem		1.312				0.015				0.984		
Impact of the breeding system												
Free Range		26.398				0.893 ^a				9.515		
Cage System		25.849				0.859 ^{ab}				11.006		
Family Business		24.419				0.842 ^b				10.758		
Sem		1.136				0.013				0.852		

There are statistically significant differences between the means indicated by different superscripts in a column (a,b,c) (p<0.05). 0,05 significance: 0,01 significance, NS: Not significant (p>0.05), SEM: Standard error of the mean (Cultivation systems (CS))

4. Conclusion

This study has revealed that the quality parameters of chicken eggs obtained from different breeding systems in Bayburt vary significantly depending on both breeding systems and seasonal factors. While the best results are obtained in the external egg quality (free-roaming for shape index and egg weight, cage system for yellow color) and internal quality data (free-roaming system); in particular, the positive effect of free-roaming systems on the nutritional content and overall internal quality of eggs strengthens the reflection of animal welfare and natural nutrition opportunities on product quality. The superiority of the cage system over the yellow color is due to the consistent effect of controlled feeding on pigmentation. It has been determined that egg yolk (protein in winter, β -carotene in spring/summer) and egg white (pH in autumn, protein in winter/summer) show significant changes with seasonal effects. As a result, our study, which emphasizes the critical importance of holistic evaluation of breeding systems and seasonal conditions while aiming at high-quality and nutritious egg production, is thought to make an important contribution to the development of sustainable production models.

Acknowledgments

This study was derived from his thesis titled ‘The Effect of the Season on the Quality Criteria of Eggs Obtained from Chickens with Different Breeding System in Bayburt’ prepared in Bayburt University Graduate School of Postgraduate Education, Department of Organic Agriculture Management. This work was supported by Research Fund of the Bayburt University. Project Number 2021/69003- 03.

Conflict of interests

Authors declare that they have no conflict of interest.

Author Contribution Declaration

The authors declare that they have contributed equally to the article.

References

- Abo Ghanima MM., Elsadek MF., Taha AE., Abd El-Hack ME., Alagawany M., Ahmed BM., Elshafie MM., El-Sabroun K. Effect of housing system and rosemary and cinnamon essential oils on layers performance, egg quality, haematological traits, blood chemistry, immunity, and antioxidant. *Animals*, 2020; 10(2): 245.
- Altan Ö. Yumurta oluşumu, kalitesi ve biyoaktif komponentleri. 2015: Ege Üniversitesi Basımevi, İzmir.
- Anonymous (International Egg). Annual Review 2016. <https://www.internationalegg.com/resources/publications.2016>.
- Anonymous (USDA), Agricultural Research Service US. <https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/methods-and-application-of-food-composition-laboratory/>. 2024.

- Bain MM., Nys Y., Dunn IC. Increasing persistency in lay and stabilising egg quality in longer laying cycles. What are the challenges? *British Poultry Science* 2016; 57(3): 330-338.
- Bouvarel I., Nys Y., Lescoat P. Improving the safety and quality of eggs and egg products, egg chemistry, production and consumption. *Woodhead Publishing Series in Food Science, Technology and Nutrition* 2011; 261-299.
- Bayraktar B., Yiğit AA., Ekici H. Serum β -carotene levels of the local black cattle in lactation period, dry period and different ages, seasons-2019. *J Vet Sci Med Diagn* 2019; 8: 272.
- Campbell D., De Haas E., Lee C. A review of environmental enrichment for laying hens during rearing in relation to their behavioral and physiological development. *Poultry Science*, 2019; 98(1): 9-28.
- Campbell D., Makagon M., Swanson J., Siegford J. Laying hen movement in a commercial aviary: Enclosure to floor and back again. *Poultry Science* 2016; 95(1): 176-187.
- Cerolini S., Zaniboni L., La Cognata R. Lipid characteristics in eggs produced in different housing systems. *Italian Journal of Animal Science* 2005; 4.
- Damaziak K., Musielak M., Musielak C., Riedel J., Gozdowski D., Grzybek W. Effect of different rearing system on eggs production, hatchability, and offspring quality in layer breeders. *Poultry Science* 2021; 100(6): 1-10.
- Dong X., Yin Z., Ma Y., Cao H., Dong D. Effects of rearing systems on laying performance, egg quality, and serum biochemistry of Xianju chickens in summer. *Poultry Science* 2017; 96(11): 3896-3900.
- Haugh H. The Haugh unit for measuring egg quality. *The U.S. Egg and Poultry Magazine*, 1937; 43, 552-555.
- Hidalgo A., Rossi M., Clerici F., Ratti S. A market study on the quality characteristics of eggs from different housing systems. *Food Chemistry* 2008; 106(3): 1031-1038.
- Huang Q., Qiu N., Ma M., Jin Y., Yang H., Geng F., Sun S. Estimation of egg freshness using S-ovalbumin as an indicator. *Poultry Science* 2012; 91(3): 739-743.
- Jones DR., Anderson KE., Guard JY. Prevalence of coliforms, Salmonella, Listeria, and Campylobacter associated with eggs and the environment of conventional cage and free-range egg production. *Poultry Science* 2012; 91(5): 1195-1202.
- Khaleel R. Prediction of Haugh unit by egg weight and albumen height. *Mesopotamia Journal of Agriculture* 2019; 47(3): 37-43.
- Kowalska E., Kucharska-Gaca J., Kuźniacka J., Lewko L., Gornowicz E., Biesek J., Adamski M. Egg quality depending on the diet with different sources of protein and age of the hens. *Scientific Reports* 2021; 11(1): 1-11.
- Küçükylmaz K., Bozkurt M., Herken EN., Çınar M., Çatlı AU., Bintaş E., Çöven F. Effects of rearing systems on performance, egg characteristics and immune response in two layer hen genotype. *Asian-Australasian Journal of Animal Sciences* 2012; 25(4): 559.

- Liu X., Wang J., Huang Q., Cheng L., Gan R., Liu L., Wu D., Li H., Geng F. Underlying mechanism for the differences in heat-induced gel properties between thick egg whites and thin egg whites: Gel properties, structure and quantitative proteome analysis. *Food Hydrocolloids* 2020; 106: 105873.
- Lordelo M., Fernandes E., Bessa R., Alves S. Quality of eggs from different laying hen production systems, from indigenous breeds and specialty eggs. *Poultry Science* 2017; 96(5): 1485-1491.
- Mathieu-Huart A., Lentdecker CD., Riviere G., Sissoko F., Rousselle C. French Agency for Food, Environmental and Occupational Health and Safety (ANSES) health reference values (RV).1 and Occupational Health & Safety 2014; 75(3): 292-301.
- Minelli G., Sirri F., Folegatti E., Meluzzi A., Franchini A. Egg quality traits of laying hens reared in organic and conventional systems. *Italian Journal of Animal Science* 2007; 6(1): 728-730.
- Moura DJD., Nääs L., Pereira D., Silva R., Camargo G. Animal welfare concepts and strategy for poultry production: a review. *Brazilian Journal of Poultry Science* 2006; 8: 137-147.
- Mugnai C., Dal Bosco A., Castellini C. Effect of rearing system and season on the performance and egg characteristics of Ancona laying hens. *Italian Journal of Animal Science* 2009; 8(2): 175-188.
- Mugnai C., Sossidou EN., Dal Bosco A., Ruggeri S., Mattioli S., Castellini C. The effects of husbandry system on the grass intake and egg nutritive characteristics of laying hens. *Journal of the Science of Food and Agriculture* 2014; 94(3): 459-467.
- Özbey O., Esen F. The effects of different breeding systems on egg productivity and egg quality characteristics of rock partridges. *Poultry Science* 2007; 86(4): 782-785.
- Pavlovski Z., Škrbić Z., Lukić M., Krnjaja V., Bijelić Z., Trenkovski S. Tehnologija proizvodnje jaja sa slobodnog ispusta posebnog i garantovanog kvaliteta (tehničko rešenje). *Biotechnology in Animal Husbandry* 2010; 26: 55-67.
- Radu-Rusu R., Usturoi M., Radu-Rusu C., Vacaru-Opris L., Leahu A., Amariei S. Chemical features, cholesterol and energy content of table hen eggs from conventional and alternative farming systems. *South African Journal of Animal Science* 2014; 44(1): 33-42.
- Rakonjac S., Bogosavljević-Bošković S., Pavlovski Z., Škrbić Z., Dosković V., Petrović MD., Petričević V. Laying hen rearing systems: A review of major production results and egg quality traits. *World's Poultry Science Journal* 2014; 70(1): 93-104.
- Rakonjac S., Bogosavljević BS., Škrbić Z., Lukić M., Dosković V., Petričević V., Petrović MD. Quality and chemical composition of eggs affected by rearing system and hen's age. *Biotechnology in Animal Husbandry* 2018; 34(3): 335-344.
- Réhault-Godbert S., Guyot N., Nys Y. The golden egg: nutritional value, bioactivities, and emerging benefits for human health. *Nutrients* 2019; 11(3): 684.
- Rizzi L., Simioli G., Martelli G., Paganelli R., Sardi L. Effects of organic farming on egg quality and welfare of laying hens. Paper presented at the XII European Poultry Conference, Verona. 2016; 10-14

- Roberts JR. Factors affecting egg internal quality and egg shell quality in laying hens. *The Journal of Poultry Science* 2004; 41(3): 161-177.
- Shan Y., Tang D., Wang R., Tu A., Yi Y., Wang X., Liu B., Zhou Y., Huang Q., Lü X. Rheological and structural properties of ovomucin from chicken eggs with different interior quality. *Food Hydrocolloids* 2020; 100, 105393.
- Sparks N. The hen's egg—is its role in human nutrition changing? *World's Poultry Science Journal* 2006; 62(2): 308-315.
- Steenfeldt S., Hammershøj M. Organic egg production. I: Effects of different dietary protein contents and forage material on organic egg production, nitrogen and mineral retention and total tract digestibility of nutrients of two hen genotypes. *Animal Feed Science and Technology*, 2015; 209: 186-201.
- Tavares BDO., Pereira DF., Salgado DDA., Mac-Lean PAB. Mortality, production and quality of eggs of different rearing systems. *Engenharia Agrícola* 2018; 38: 478-485.
- Türker İ., Alkan S. Comparisons of physical and chemical characteristics of eggs obtained using hens reared in deep litter and free-range systems. *Journal of Agricultural Sciences* 2019; 25(2): 181-188.
- Wang J., Um P., Dickerman BA., Liu J. Zinc, magnesium, selenium and depression: a review of the evidence, potential mechanisms and implications. *Nutrients* 2018; 10(5): 584.
- Wei S., Guo Y., Yan P. Comparison of two housing systems on behaviour and performance of fattening pigs. *Journal of Applied Animal Research* 2019; 47(1): 41-45.
- Yenice G., Kaynar O., Ileriturk M., Hira F., Hayirli A. Quality of eggs in different production systems. *Czech Journal of Food Sciences* 2016; 34(4): 370-376.