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Authors' contributions Please specify the authors' role using this form.	Conceptualization: Çam M. Data curation: Kaya ZK, Güler S

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Abstract

The present study was conducted with the aim of investigating the effect of storage length, turning frequency and egg position on internal quality traits of chukar eggs obtained from 56-week-old Chukar partridges under the same nutrition and management conditions. A total of 720 eggs were collected and assigned to 36 subgroups according to storage length (7,14, 21 and 28 d), turning frequency (0, 1 and 24 per day) and egg position (pointed end up, blunt end up and horizontal). As a result of the study, almost all the internal quality traits of Chukar eggs were negatively affected by lengthening of storage period especially 21 days and longer ($p < 0.001$). Turning frequency wasn't statistically affected by internal quality traits except yolk index ($p < 0.01$). An improvement was observed in Haugh unit, albumen index and heigh of eggs stored with pointed end up ($p < 0.001$). Some significant interactions occurred among all internal egg quality traits which were mostly dependent on the eggs stored horizontally, extended storage time more than 21 days and egg turning during storage. The results and interactions showed that internal quality traits would be preserved well for the eggs stored less than 21 days with the position of pointed end up independent of turning. If the storage period was to exceed 21 days, the eggs should be positioned horizontally and turning should be applied to preserve the quality of chukar eggs.

Keywords: Chukar partridge, egg position, egg quality, storage period, turning frequency

Introduction

Storing eggs is one of the most necessary ways of the poultry industry given the fact that daily egg incubation or transportation is inefficient due to economical reasons. In addition, nutrient values of daily collected fresh eggs decrease from albumen to embryo phases and impair gaseous transportation between embryo and environment [1]. At intensive poultry farms, the daily collected eggs are laid on the storage chambers and then held for a while at 15-20°C and 75-80% relative humidity [2]. Egg production of partridge eggs were fluctuated throughout breeding season [3]. These seasonal changes of partridge eggs production cause the need to hold the eggs for longer period to obtain sufficient quantity of eggs for incubation.

Partridge breeding is getting popular as game birds in the several Mediterranean countries including Turkey. Chukar partridge is one of the most popular species among game birds. Due to not only higher valuable of its chicks but also lower egg production of hens in poultry industry, all chukar eggs obtained from breeding farms are aimed to be incubated. For these reasons, several studies have been conducted to describe optimum storage conditions of partridges.

Despite the fact that egg storage time is known not to exceed 1 week in the poultry industry [2] which was probably due to albumen degradation with longer storage period [4]; many researchers have proved partridge eggs are more durable to longer storage period [5-7]. According to Caglayan, Alasahan [6], the internal quality of partridge eggs was deteriorated by long storage time. This could be attributed to the fact that long storage time can cause the decrease of albumen viscosity which might be detrimental effect on the hatching of eggs [4]. But Gunhan and Kirikci [7] stated that the partridge eggs could resist protein degradation in the long-term storage period. The turning of eggs during long storage period wase reported to have some beneficial effects particularly on low quality eggs [8-11]. Elibol and Brake [11] explained the egg quality might be deteriorated by different positions of eggs in the storage period. Ayeni, Agbede [4] described different positions of eggs during storage would have different effects on hatching process. However, the recommendations of these authors were generally based on the results of hatching performance and none of them about how to change egg quality traits in different storage conditions were made clear. In addition, scientific studies of partridge egg quality assessment in different conditions during storage period are still lacking. It's also hypothesized that turning the eggs with small end up position during long storage time might prevent those from adverse effects of deteriorating the albumen and development of chorioallantoic membrane [4]. Thus, this study was aimed to investigate the impact of storage conditions such as storage time, turning frequency, egg position and their potential interactions on egg quality traits of chukar partridge in the storage period prior to incubation.

Materials and Methods

Breeder flock and husbandry

This study was carried out at Bahri Dagdas International Agricultural Research Institute (37° 52′ 5.7612" and 32° 33′ 12.8088"), the climate of which was steppe (cold semi-arid). 56-week-old Chukar partridges were kept in semi-open

wire mesh cages size of which 6,0 x 1,2 x 1,5 m as 30 females and 10 males. Average egg production at the time interval when the study was carried out was 14 eggs per each cage. In addition to natural photoperiod, an artificial lighting program was implemented at a rate of 1 h artificial light per week after obtaining the first egg at 36-weeks age. The artificial lighting program was terminated after making a total of 16 h. The partridges were fed with the same ration ad libitum (Table 1). The needs of water were met ad libitum with automatic nipples.

Table 1 here

Experimental design

Daily fresh chukar eggs were numbered and assigned to three experimental group consisting of randomly selected eggs weighing 19-24 g [12]. Experimental groups were designed as storage length (7, 14, 21 and 28 d), turning frequency (0, 1 and 24 times a day) and egg position (blunt end up, pointed end up and horizontal). Totally, 720 eggs were used consisting of 20 eggs per each subgroup. All the eggs were randomly allocated to the subgroups. The eggs were collected 4 consecutive days according to the storage length. For the forming of 3 different turning groups, the eggs were set into 3 same model of storage chambers (HD-960L-3in1) at average 15°C and 75% relative humidity. All the subgroups were homogenously distributed into the chambers for the same microclimate conditions. The storage chambers were in the same storage room under same environmental conditions with the location of near the breeding cages. The eggs at the turning groups were turned as 45° angle from vertical plane in the storage chambers.

Measuring Egg Quality

Following the same day at the end of storage period per each storage length group; eggs were weighed individually. The eggs were broken onto round glass table and sit for approximately 5 min. to measure albumen width, albumen length, albumen height, yolk diameter and yolk height of eggs with an electronic digital calipper (Kanon EMS-150). Albumen height was measured in the middle of thick albumen from equal distances to the outer corners of albumen. Following separation of yolk from albumen; albumen weight, eggshell weight and yolk weights were weighed using an electronic balance with 0.01 precision. The other traits of eggs were calculated according to the following equations belowx [13].

(1) Albumen index (%): [(Albumen height / (albumen length + albumen width)/2)] × 100

(2) Albumen weight (g): Egg weight – (yolk weight + shell weight)

(3) Albumen ratio (%): (Albumen weight / egg weight) × 100

(4) Yolk index (%): (Yolk height / yolk diameter) × 100

(5) Yolk ratio (%): (Yolk weight / egg weight) × 100

(6) Yolk / albumen ratio: (Yolk weight / albumen weight) × 100

(7) Haugh Unit: $100\log[\text{albumen height} - (1.7 \times \text{egg weight}^{0.37}) + 7.57]$

(8) Shell ratio (%): (Shell weight / egg weight) × 100

Statistical analyses

The data of 29 eggs were discarded from the study due to data errors. Differences among experimental groups to determine egg quality traits were analysed by (GLM) General Linear Model (SPSS ver. 25.0). Storage length, turning frequency, egg position and their interactions was included in the model as fixed effects. To determine differences among multiple groups means, Bonferroni correction test was used considering 5% probability.

Results

Some Egg Quality Traits

Some chukar egg quality parameters with different storage length, turning frequency and egg position groups and their effects were given in Table 2 and Table 3 respectively. Storage length showed significant effect on almost all quality parameters illustrated in Table 2 ($p < 0.001$). Significant differences occurred dramatically after 21-d of storage period. Turning frequency didn't have any significant effect on these quality parameters except for yolk height which observed highest results in the eggs turned 24 times a day. Significant effects with different results among egg position groups were found on the egg quality traits such as yolk diameter, albumen length and height ($p < 0.01$).

Table 2 and 3 here.

Main Egg Quality Traits

The effect of storage length, turning frequency and egg position on albumen index, yolk index and Haugh unit which are the main egg quality traits were presented in Table 5, and subgroup means of the fixed factors were also

presented in Table 4. Storage length showed a significant effect on all the major quality traits ($p < 0.001$). Either numerical or statistical differences became prominent after 21 days storage period. The only significant effect was observed on yolk index between turning frequency groups ($p < 0.01$). The eggs stored with pointed end up were found to be highest values in terms of albumen index and Haugh unit ($p < 0.001$).

Table 4 and 5 here.

Weight of Egg Components

The weights of egg components in different storage length, turning frequency and egg position were illustrated in Table 6, and the effect of those factors on egg weight components were given in Table 7. Significant effects on each egg weight components were mostly more evident after 21 days storage period. Neither turning frequency nor egg position had significant effect on egg weight components except for the fact that yolk weight had the highest values for the eggs stored with pointed end up.

Table 6 and 7 here.

Egg Component Ratios

Egg component ratios in different storage length, turning frequency and egg position were given in Table 8. The effect of fixed factors was also given in Table 9. The ratio of egg components was significantly affected by lengthening of storage time ($p < 0.001$). Prominent differences were observed after 21 days of storage period. Turning frequency had no significant effect on those ratios. Proportions of albumen and yolk components were significantly differed by egg position during storage. There was no significant difference on shell ratio of the eggs with different egg position.

Table 8 and 9 here.

Interactions Between Traits

Some significant interactions among factors for all quality traits were observed in the study (Table 3, Table 5). The significant interactions were summarized by interpretation of one-way analysis which the raw means of subgroups could be seen in Table 1 and Table 3. Storage length and egg position had significant interaction among all quality traits ($p < 0.05$). This interaction was mostly based on the eggs stored with horizontal position or lengthening storage period more than 21 days. Albumen width and length were decreased as the storage period was lengthened while

albumen height didn't have any significant effect on the eggs in the horizontal group. Significant differences occurred in the eggs stored for 28 days, which was found to be highest yolk diameter in eggs stored with the position of pointed end up. Therefore, these findings about yolk diameter resulted in significant differences for yolk index in eggs with 28 days storage duration. Yolk height was reported to be lower in eggs stored with horizontal position than those stored with blunt end up position. Normally, Haugh unit, albumen height and index of eggs stored with pointed end up were significantly higher values which disappeared when the eggs were stored more than 21 days storage length. Contrary to other position groups, albumen index and Haugh unit weren't influenced by different storage duration in the eggs stored horizontally. As for yolk index, significant difference only occurred in the 28 days of storage duration. There was a significant interaction between turning frequency and egg position for both Haugh unit and albumen quality traits ($p < 0.05$). These results were mostly based on the eggs when turning was applied. Increasing turning frequency resulted in decreased albumen length in eggs stored with blunted end up position. When turning frequency was once a day during storage period, albumen height was lower in eggs stored with horizontal position than those stored with the position of pointed end up. Turning the eggs 24 times a day resulted in decreased albumen index in the position group of blunted end up and increased albumen index in the horizontal position group. Turning the eggs 24 times a day resulted in increased albumen index compared to non-turned eggs in the position group of blunted end up. A significant increase occurred in Haugh unit of the eggs with pointed end up when the eggs were turned once a day during storage period. Significant interactions also occurred between storage length, turning frequency and egg position for all quality traits except albumen width and Haugh unit ($p < 0.05$). There was no interaction between factors for egg component traits except the interaction of storage length with turning frequency for yolk weight ($p < 0.01$) and albumen ratio ($p < 0.05$).

Discussion

Storage Length

The observed results proved the fact how chukar egg quality can change in the mentioned factors of different egg conditions. We didn't need to investigate the effect of eggshell quality and shape traits because the eggshell quality was mainly affected by many factors apart from storage conditions [14]. Contrary to our results, albumen length and width was reported to show an increase with long term storage time [15]. Albumen height and index, yolk index and

159 Haugh unit of chukar eggs decreased significantly as the storage period lengthened which agrees with the findings
160 of rock partridges [6, 12]. But most of these decreases were found in the eggs after 21 days of storage period. These
161 results confirmed the study of Gunhan and Kirikci [7] who found a fluctuation in most of egg quality parameters of
162 rock partridge till 21 days of storage time and then more evident significant differences. The main possible
163 explanation of this result is that partridge eggs are resistant to longer storage duration compared with other poultry
164 species [7, 16, 17]. Other explanations are that albumen height is one of the measures of the albumen viscosity
165 which plays an important role to obtain sufficient nutrients by the blastoderm in the early period of incubation [18].
166 Extended storage time caused excessive albumen degradation, the result of which albumen got thinner and watery,
167 and therefore caused a decrease in Haugh unit which might cause higher embryonic death in the early period of
168 incubation [19]. Khan, Khan [20] reported that prolonged storage period impairs egg quality parameters due to water
169 loss from the eggs. Although yolk diameter and height showed a fluctuation up to 21 days of storage, significant
170 increase for yolk diameter and decrease for its height was observed in the current study. These findings supported
171 the ideas of Kirunda and McKee [21], who reported that weakening vitelline membrane and chalazae caused an
172 increase in yolk diameter and a decrease in its height during prolonged storage period. When the yolk diameter gets
173 larger with long storage duration, yolks become fragile and eventually tend to mix up with albumen [22].

174 Chukar egg components weights and their ratios were significantly differed by storage length. Prolonged
175 storage period decreased the albumen weight and increased yolk weight in current study. The differences in these
176 components were based on the move of water from albumen to yolk during the long storage period in relation with
177 changes in the permeability of the vitelline membrane [20]. As for proportions of egg components, while albumen
178 ratio decreased; shell and yolk ratio increased with long-term storage duration. This was mostly related to a loss in
179 albumen weight over time [23]. Findings of rock partridges by Caglayan, Alasahan [6] and Gunhan and Kirikci [7]
180 were in agreement with ours. In the current study, significant interaction was observed between storage length and
181 turning frequency only for yolk weight and albumen ratio. Melo, Araújo [24] found an interaction between eggshell
182 weight of broiler breeders with different storage length and turning frequency but they didn't find any interaction
183 for proportions of other components.

In the current study egg quality and egg components had no significant interaction between storage length and turning frequency. Melo, Araújo [24] reported that 12 days of holding period had an adverse effect on quality of broiler breeder eggs independent of turning. But they found significant interaction for the egg components when the eggs stored less than 12 days. This difference from our results might be based on inclination of the eggs during turning which these authors turned the eggs by 180° angle.

Egg Turning

The previous studies indicated that egg turning during storage might be applicable for incubation yields and embryonic mortality [9, 10, 25], but the effect of those on egg quality traits hasn't been fully documented yet. The study shows that almost all of chukar egg quality traits and egg weight components weren't obviously affected by turning during storage. Several authors similarly confirmed that the turning of partridge eggs during storage period had no obvious significant effect on hatching results [10, 25]. But significant interactions occurred for the eggs with different position during storage when turning was applied, which were similar to the findings of Proudfoot [26]. The previous literatures investigating the effect of turning on egg quality during storage is lacking, which makes it hard to discuss this research.

Egg Position

Egg position during storage affects incubation period and hatchability results. Several investigators researched the hatchability results of chicken eggs with different position during storage [4, 11, 27]. However, there is a lack of research investigation about how egg quality would change in different conditions of storage. The study confirms that eggs stored with pointed end up would have better quality considering almost all of quality parameters. Several authors found similar results for eggs stored with pointed end up with regard to hatchability and embryonic mortality [4, 11, 27]. These significant differences between egg position groups disappeared after 21 days of storage period. This might be mainly due to eggs stored horizontally, which wasn't negatively influenced by lengthening storage period. These significant interactions between storage length and egg position are probably due to the changes of yolk position and blastoderm location in the equatorial region of eggs during storage period [1]. The findings of Cardetti, Rhorer [28] indicated that yolk was more centered in the eggs stored horizontally. Yolk

centralization was also known as one of the factors determining the egg quality [29]. These might be possible explanations why egg quality of the eggs stored horizontally was more durable in long-term storage period. The findings of highest albumen rate and lowest yolk rate in the chukar eggs stored horizontally might also indicate durability of those stored in long-term storage. According to the findings in the study by Burkhardt, Meister [30], eggs placed with horizontal position in the last days of the storage were essential for proper location of germinal disc.

Conclusion

The results of the present study showed that the significant differences for chukar egg quality traits were mainly due to egg storage length and egg position. The obvious effect on internal egg quality traits was observed especially with more than 21 days storage length. Generally, storing the chukar eggs less than 21 days with the position of pointed end up is necessary to ensure sufficient quality of the eggs independent of turning. However, if the storage length is to exceed 21 days, the eggs can be placed horizontally and turning should be applied to preserve the quality of chukar eggs. More comprehensive research with different poultry species is essential for general recommendations about how egg quality differs in different storage conditions.

References

1. Brake J, Walsh T, Benton Jr C, Petitte J, Meijerhof R, Penalva G. Egg handling and storage. Poult Sci. 1997;76(1):144-51. https://doi.org/10.1093/ps/76.1.144

2. Fasenko G. Egg storage and the embryo. Poult Sci. 2007;86(5):1020-4. https://doi.org/10.1093/ps/86.5.1020

3. González-Redondo P. Influence of the Laying Date on the Fertility and Hatchability of Red-Legged Partridge (Alectoris rufa) Eggs. Journal of Applied Poultry Research. 2006;15(4):579-83. https://doi.org/10.1093/japr/15.4.579

4. Ayeni AO, Agbede JO, Igbasan FA, Onibi GE, Adegbenro M. Effects of storage periods and positioning during storage on hatchability and weight of the hatched chicks from different egg sizes. Bull Natl Res Cent. 2020;44(1):1-6. https://doi.org/10.1186/s42269-020-00362-4

5. Tilki M, Saatci M. Effects of storage time on external and internal characteristics in partridge (Alectoris graeca) eggs. Rev Med Vet. 2004;155(11):561-4.

6. Caglayan T, Alasahan S, Kirikci K, Gunlu A. Effect of different egg storage periods on some egg quality characteristics and hatchability of partridges (Alectoris graeca). Poult Sci. 2009;88(6):1330-3. https://doi.org/10.3382/ps.2009-00091

7. Gunhan S, Kirikci K. Effects of different storage time on hatching results and some egg quality characteristics of rock partridge (A. graeca) (Management and production). Poult Sci. 2017;96(6):1628-34. https://doi.org/10.3382/ps/pew443

8. Damaziak K, Pawęska M, Gozdowski D, Niemiec J. Short periods of incubation, egg turning during storage and broiler breeder hens age for early development of embryos, hatching results, chicks quality and juvenile growth. Poult Sci. 2018;97(9):3264-76. https://doi.org/10.3382/ps/pey163

9. Elibol O, Peak S, Brake J. Effect of flock age, length of egg storage, and frequency of turning during storage on hatchability of broiler hatching eggs. Poult Sci. 2002;81(7):945-50. https://doi.org/10.1093/ps/81.7.945

10. González-Redondo P, Martínez-Domínguez A. Comparison of several turning frequencies during the storage period of red-legged partridge (Alectoris rufa) hatching eggs. Braz J Poult Sci. 2019;21(3). https://doi.org/10.1590/1806-9061-2018-0882

11. Elibol O, Brake J. Effect of egg position during three and fourteen days of storage and turning frequency during subsequent incubation on hatchability of broiler hatching eggs. Poult Sci. 2008;87(6):1237-41. https://doi.org/10.3382/ps.2007-00469

12. Kırıkçı K, Çam M, Başer E, Akbulut NK, Bilgiç MA. Kınalı kekliklerde yumurta ağırlığının kuluçka sonuçları üzerine etkisi. Bahri Dağdaş Hayvancılık Araştırma Dergisi. 2018;7(1):1-6.

13. Alkan S, Galiç A, Karsli T, Karabağ K. Effects of egg weight on egg quality traits in partridge (Alectoris chukar). J Appl Anim Res. 2015;43(4):450-6. https://doi.org/10.1080/09712119.2014.980419

14. Wolford J, Tanaka K. Factors influencing egg shell quality - A review. Worlds Poult Sci J. 1970;26(4):763-80. https://doi.org/10.1079/WPS19700033

15. Şekeroğlu A, Sarıca M, Demir E, Ulutaş Z, Tilki M, Saatçi M. The effects of housing system and storage length on the quality of eggs produced by two lines of laying hens. Arch für Geflugelkunde. 2008;72(3):106-9.

16. González-Redondo P. Effect of long-term storage on the hatchability of red-legged partridge (Alectoris rufa) eggs. Poult Sci. 2010;89(2):379-83. https://doi.org/10.3382/ps.2009-00408

17. Gomez-de-Travecedo P, Caravaca F, González-Redondo P. Effects of storage temperature and length of the storage period on hatchability and performance of red-legged partridge (Alectoris rufa) eggs. Poult Sci. 2014;93(3):747-54. https://doi.org/10.3382/ps.2013-03329

18. Benton Jr C, Brake J. The effect of broiler breeder flock age and length of egg storage on egg albumen during early incubation. Poult Sci. 1996;75(9):1069-75. https://doi.org/10.3382/ps.0751069

19. Lapao C, Gama L, Soares MC. Effects of broiler breeder age and length of egg storage on albumen characteristics and hatchability. Poult Sci. 1999;78(5):640-5. https://doi.org/10.1093/ps/78.5.640

20. Khan MJ, Khan SH, Bukhsh A, Amin M. The effect of storage time on egg quality and hatchability characteristics of Rhode Island Red (RIR) hens. Vet Arh. 2014;84(3):291-303.

21. Kirunda D, McKee S. Relating quality characteristics of aged eggs and fresh eggs to vitelline membrane strength as determined by a texture analyzer. Poult Sci. 2000;79(8):1189-93. https://doi.org/10.1093/ps/79.8.1189

22. Nasri H, van den Brand H, Najar T, Bouzouaia M. Interactions between egg storage duration and breeder age on selected egg quality, hatching results, and chicken quality. Animals. 2020;10(10):1719. https://doi.org/10.3390/ani10101719

23. Scott T, Silversides FG. The effect of storage and strain of hen on egg quality. Poult Sci. 2000;79(12):1725-9. https://doi.org/10.1093/ps/79.12.1725

24. Melo E, Araújo I, Triginelli M, Castro F, Baião N, Lara L. Effect of egg storage duration and egg turning during storage on egg quality and hatching of broiler hatching eggs. Animal. 2021;15(2):100111. https://doi.org/10.1016/j.animal.2020.100111

25. Woodard AE, Morzenti A. Effect of turning and age of egg on hatchability in the pheasant, chukar, and Japanese quail. Poult Sci. 1975;54(5):1708-11. https://doi.org/10.3382/ps.0541708

26. Proudfoot F. Hatchability of stored chicken eggs as affected by daily turning during storage and prewarming and vacuuming eggs enclosed in plastic with nitrogen. Can J Anim Sci. 1966;46(1):47-50. https://doi.org/10.4141/cjas66-008

27. Tiwary AK, Maeda T. Effects of egg storage position and injection of solutions in stored eggs on hatchability in chickens (Gallus domesticus). J Poult Sci. 2005;42(4):356-62. https://doi.org/10.2141/jpsa.42.356

28. Cardetti MM, Rhorer A, Stadelman W. Effect of egg storage position on consumer quality attributes of shell eggs. Poult Sci. 1979;58(5):1403-5. https://doi.org/10.3382/ps.0581403

29. Stadelman W. The preservation of quality in shell eggs. In: Stadelman W, Cotteril O, editors. Egg science and technology. 4th ed. Routledge: CRC Press; 1995. p. 67-79.

30. Burkhardt A, Meister S, Bergmann R, Koch E. Influence of storage on the position of the germinal disc in the fertilized unincubated chicken egg. Poult Sci. 2011;90(10):2169-73. https://doi.org/10.3382/ps.2010-01179

Tables and Figures

Table 1. The ingredients and chemical composition of partridge diet

Ingredients	%
Wheat	37,28
Maize	24,90
Boncalite	5,00
Vegetable oil	3,00
Soybean meal, %48	19,10
Marble powder	6,37
Dicalcium phosphate 18	2,78
L-lysine hydrochloride	0,88
Salt	0,42
Vitamin-Mineral Premix*	0,25
DL-methionine	0,02
Calculated nutrient concentration	
ME kcal/kg	2800
CP % KM	18
Ca %	3,11
P %	0,61
Lysine %	1,5
Methionine + Cystine%	0,6

*Premix provided the following per kg of diet:Vitamin A: 8.800 IU, vitamin D3: 2.200 IU, vitamin E: 11 mg, nicotinic acid: 44 mg, Cal-DPantotenat: 8.8 mg, riboflavin: 4.4 mg, thiamine: 2.5 mg, vitamin B12: 6.6 mg, folic acid: 1 mg, D-Biotin: 0.11 mg, colin: 220 mg, Mn: 80 mg, Cu: 5 mg, Fe: 60 mg, Zn: 60 mg, Co: 0.20 mg, iodine: 1 mg, Se: 0.15 mg

Table 2. Some quality traits (mm) of chukar partridge eggs in different storage length, turning frequency and egg position during storage period

SL (d)	TF (times/d)	EP	n	AW	AL	AH	YW	YH
		PEU	18	39.46	54.25	4.59	30.10	11.98
	0	**BEU**	18	39.34	53.61	4.72	29.87	12.55
		H	17	44.72	62.52	4.42	29.60	12.45
		PEU	20	39.44	54.79	5.10	30.09	12.59
7	**1**	**BEU**	20	38.58	52.48	4.46	30.13	12.23
		H	19	43.56	60.73	4.05	30.77	12.08
		PEU	20	40.22	57.98	4.68	30.40	12.91
	24	**BEU**	20	39.58	56.17	4.43	30.45	12.44
		H	20	40.91	54.60	4.67	29.71	12.65
		PEU	16	39.08	58.82	4.85	30.09	13.24
	0	**BEU**	17	41.04	57.88	4.48	30.79	12.75
		H	20	40.11	60.34	4.22	30.25	12.63
		PEU	19	37.80	54.66	4.43	30.41	12.48
14	**1**	**BEU**	20	42.28	61.02	4.39	29.95	13.21
		H	20	39.33	57.69	4.23	30.80	12.53
		PEU	20	40.47	56.08	4.44	30.64	13.16
	24	**BEU**	20	42.44	59.36	4.47	29.73	13.16
		H	18	41.12	61.53	4.23	30.12	12.74
		PEU	20	40.64	56.58	4.32	31.98	12.47
	0	**BEU**	19	40.13	56.87	4.35	30.40	12.65
		H	16	39.91	57.41	4.22	30.77	12.53
		PEU	19	39.71	56.74	4.28	31.49	12.21
21	**1**	**BEU**	17	39.94	55.57	4.00	31.27	12.47
		H	18	39.33	57.50	4.26	31.03	12.23
		PEU	19	40.54	57.10	4.17	30.87	12.35
	24	**BEU**	18	40.65	58.60	4.07	31.02	12.66
		H	18	38.63	53.65	4.32	30.89	12.40
		PEU	17	42.13	57.39	4.10	33.54	11.99
	0	**BEU**	19	38.06	52.94	4.03	31.30	11.96
		H	18	38.21	57.81	4.13	32.11	12.05
		PEU	20	39.69	53.20	4.33	32.77	11.54

28	**1**	**BEU**	19	41.15	56.94	4.23	32.08	11.82
		H	16	38.73	54.71	4.16	31.31	12.15
		PEU	19	38.71	54.57	4.06	32.12	12.15
	24	**BEU**	20	43.09	57.05	3.84	32.22	11.74
		H	18	38.33	55.93	4.21	31.20	12.42

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal; AW, albumen width; AL, albumen length; AH, albumen height; YW, yolk width; YH, yolk height.

Table 3. The effect of some quality traits (mm) on storage length, turning frequency and egg position during storage period

		n	AW	AL	AH	YW	YH
SL (d)	**7**	172	40.65	56.35^{b}	4.57^{a}	30.12^{c}	12.43^{b}
	14	170	40.41	58.60^{a}	4.42^{ab}	30.31^{c}	12.88^{a}
	21	164	39.94	56.67^{ab}	4.22^{bc}	31.08^{b}	12.44^{b}
	28	166	39.79	55.61^{bc}	4.13^{c}	32.08^{a}	11.98^{c}
	SEM		0.39	0.46	0.04	0.11	0.06
	***p*-value**		-	***	***	***	***
TF (times/d)	**0**	215	40.23	57.20	4.37	30.90	12.44^{ab}
	1	227	39.96	56.33	4.34	31.01	12.30^{b}
	24	230	40.39	56.89	4.30	30.78	12.57^{a}
	SEM		0.33	0.40	0.04	0.10	0.05
	***p*-value**		-	-	-	-	**
EP	**PEU**	227	39.82	56.01^{b}	4.45^{a}	31.16^{a}	12.42
	BEU	227	40.52	56.54^{ab}	4.29^{b}	30.82^{b}	12.47
	H	218	40.24	57.87^{a}	4.27^{b}	30.72^{b}	12.40
	SEM		0.33	0.40	0.04	0.10	0.05
	***p*-value**		-	**	**	***	-
Interactions				***p*-value**			
SL × TF			-	-	-	-	-
SL × EP			***	**	*	*	**
TF × EP			-	**	*	-	-
SL × TF × EP			-	***	*	**	*

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal; AW, albumen width; AL, albumen length; AH, albumen height; YW, yolk width; YH, yolk height.

$^{a, b, c}$ Means along the same column with different superscripts are significantly (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$) different.

Table 4. Major quality traits of chukar partridge eggs in different storage length, turning frequency and egg position during storage period

SL (d)	TF (times/d)	EP	n	AI (%)	YI (%)	HU
7	0	PEU	18	2.46	39.88	83.97
		BEU	18	2.59	42.37	84.53
		H	17	2.08	42.11	82.93
	1	PEU	20	2.74	41.96	86.65
		BEU	20	2.47	40.67	83.04
		H	19	1.98	39.26	80.18
	24	PEU	20	2.40	42.53	84.53
		BEU	20	2.36	40.88	82.87
		H	20	2.48	42.72	84.46
14	0	PEU	16	2.51	44.16	85.46
		BEU	17	2.30	41.64	83.37
		H	20	2.13	41.80	82.04
	1	PEU	19	2.43	41.10	83.19
		BEU	20	2.15	44.19	82.52
		H	20	2.21	40.75	81.57
	24	PEU	20	2.31	43.05	82.61
		BEU	20	2.20	44.37	83.27
		H	18	2.08	42.36	81.66
21	0	PEU	20	2.23	39.85	82.40
		BEU	19	2.27	40.86	82.62
		H	16	2.17	40.80	81.80
	1	PEU	19	2.23	38.89	81.92
		BEU	17	2.11	40.04	80.56
		H	18	2.22	39.48	82.31
	24	PEU	19	2.17	40.05	81.08
		BEU	18	2.08	40.92	80.62
		H	18	2.35	40.26	82.19
	0	PEU	17	2.06	35.83	80.58
		BEU	19	2.22	38.22	80.34
		H	18	2.19	37.62	81.27

		PEU	20	2.34	35.25	82.67
28	**1**	**BEU**	19	2.18	36.85	82.03
		H	16	2.26	38.80	81.36
		PEU	19	2.22	37.87	80.56
	24	**BEU**	20	2.11	36.49	79.01
		H	18	2.23	39.84	81.53

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal; AI, albumen index; YI, yolk index; HU, Haugh unit.

Table 5. The effect of major quality traits on storage length, turning frequency and egg position during storage period

		n	AI (%)	YI (%)	HU
SL (d)	**7**	172	2.40[a]	41.38[b]	83.70[a]
	14	170	2.26[ab]	42.60[a]	82.79[ab]
	21	164	2.20[b]	40.13[c]	81.74[b]
	28	166	2.18[b]	37.42[d]	81.03[b]
	SEM		0.03	0.25	0.29
	***p*-value**		***	***	***
TF (times/d)	**0**	215	2.27	40.43[ab]	82.58
	1	227	2.28	39.77[b]	82.38
	24	230	2.24	40.95[a]	82.51
	SEM		0.03	0.22	0.25
	***p*-value**		-	**	-
EP	**PEU**	227	2.34[a]	40.04	82.97[a]
	BEU	227	2.24[b]	40.63	82.06[b]
	H	218	2.20[b]	40.48	81.96[b]
	SEM		0.03	0.22	0.25
	***p*-value**		**	-	**
Interactions			***p*-value**		
SL × TF			-	-	-
SL × EP			***	**	*
TF × EP			***	-	*
SL × TF × EP			*	***	-

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal; AI, albumen index; YI, yolk index; HU, Haugh unit.

[a, b, c, d] Means along the same column with different superscripts are significantly (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$) different.

Table 6. Weight of chukar egg components (g) in different storage length, turning frequency and egg position during storage period

SL (d)	TF (times/d)	EP	n	Yolk	Albumen	Shell
7	0	PEU	18	6.93	11.89	1.89
		BEU	18	6.98	12.14	1.86
		H	17	6.74	12.08	1.93
	1	PEU	20	7.08	12.15	1.97
		BEU	20	6.95	12.09	1.91
		H	19	6.93	12.33	1.92
	24	PEU	20	7.28	11.69	1.89
		BEU	20	7.00	11.89	1.91
		H	20	6.93	12.06	1.93
14	0	PEU	16	7.12	11.89	1.95
		BEU	17	6.92	11.65	1.97
		H	20	6.82	11.40	1.88
	1	PEU	19	7.01	11.63	1.93
		BEU	20	7.40	11.80	1.93
		H	20	7.13	11.73	1.98
	24	PEU	20	7.08	12.49	1.93
		BEU	20	7.13	11.72	1.90
		H	18	7.91	11.97	1.92
21	0	PEU	20	7.34	11.16	1.96
		BEU	19	7.18	11.34	2.00
		H	16	6.96	11.68	1.88
	1	PEU	19	7.18	11.69	1.95
		BEU	17	7.08	11.24	1.93
		H	18	6.82	11.31	1.91
	24	PEU	19	7.12	11.69	2.02
		BEU	18	7.42	11.46	2.03
		H	18	7.31	11.76	2.00
	0	PEU	17	7.87	11.26	1.99
		BEU	19	7.57	11.13	2.02
		H	18	7.59	11.31	1.97

		PEU	20	7.37	11.03	1.97
28	**1**	**BEU**	19	7.27	11.80	1.95
		H	16	7.25	11.35	2.01
		PEU	19	7.51	11.29	1.96
	24	**BEU**	20	7.39	11.36	2.01
		H	18	7.47	11.42	1.98

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal.

Table 7. The effect of weight of chukar egg components (g) on storage length, turning frequency and egg position during storage period

		n	Yolk	Albumen	Shell
SL (d)	**7**	172	6,98^{b}	12,03^{a}	1,91^{c}
	14	170	7,06^{b}	11,81^{a}	1,93^{bc}
	21	164	7,16^{b}	11,48^{b}	1,97^{ab}
	28	166	7,48^{a}	11,22^{b}	1,98^{a}
	SEM		0,05	0,07	0,01
	***p*-value**		***	***	**
TF (times/d)	**0**	215	7,17	11,58	1,94
	1	227	7,12	11,60	1,95
	24	230	7,21	11,73	1,96
	SEM		0,04	0,06	0,01
	***p*-value**		-	-	-
EP	**PEU**	227	7,24^{a}	11,66	1,95
	BEU	227	7,19^{ab}	11,55	1,95
	H	218	7,07^{b}	11,70	1,94
	SEM		0,04	0,06	0,01
	***p*-value**		*	-	-
Interactions			***p*-value**		
	SL × TF		**	-	-
	SL × EP		-	-	-
	TF × EP		-	-	-
	SL × TF × EP		-	-	-

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal.

$^{a, b, c}$ Means along the same column with different superscripts are significantly (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$) different.

Table 8. Ratio of chukar egg components (%) in different storage length, turning frequency and egg position during storage period

SL (d)	TF (times/d)	EP	n	Albumen	Yolk	Albumen/Yolk	Shell
7	0	PEU	18	57.36	33.53	58.82	9.11
		BEU	18	57.84	33.26	57.73	8.89
		H	17	58.19	32.50	56.17	9.31
	1	PEU	20	57.32	33.42	58.44	9.26
		BEU	20	57.65	33.25	57.97	9.10
		H	19	58.15	32.77	56.71	9.09
	24	PEU	20	55.98	34.94	62.60	9.08
		BEU	20	57.10	33.72	59.16	9.18
		H	20	57.59	33.17	57.83	9.24
14	0	PEU	16	56.71	34.00	60.44	9.29
		BEU	17	56.73	33.70	59.79	9.56
		H	20	56.69	33.97	60.34	9.34
	1	PEU	19	56.50	34.11	60.67	9.38
		BEU	20	55.78	35.08	64.81	9.13
		H	20	56.24	34.26	61.28	9.50
	24	PEU	20	58.11	32.90	57.13	8.99
		BEU	20	56.45	34.40	61.24	9.15
		H	18	57.50	33.24	57.94	9.26
21	0	PEU	20	54.55	35.85	66.01	9.60
		BEU	19	55.19	35.04	63.94	9.77
		H	16	56.93	33.93	59.76	9.14
	1	PEU	19	56.14	34.49	61.63	9.37
		BEU	17	55.45	35.01	63.53	9.54
		H	18	56.45	34.01	60.57	9.54
	24	PEU	19	56.05	34.23	61.42	9.72
		BEU	18	54.78	35.53	65.07	9.69
		H	18	55.86	34.64	62.31	9.50
	0	PEU	17	53.32	37.24	70.18	9.44
		BEU	19	53.69	36.56	68.30	9.75
		H	18	54.17	36.39	67.41	9.44

		PEU	20	54.22	36.13	67.11	9.65
28	**1**	**BEU**	19	53.91	36.35	67.80	9.74
		H	16	55.04	35.21	64.13	9.75
		PEU	19	54.35	36.22	67.06	9.44
	24	**BEU**	20	54.76	35.58	65.32	9.66
		H	18	54.71	35.81	65.80	9.48

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal.

Table 9. The effect of storage length, turning frequency and egg position during storage period on weight of chukar egg components (%)

		n	Albumen	Yolk	Albumen/Yolk	Shell
SL (d)	**7**	172	57.47^{a}	33.40^{c}	58.38^{c}	9.14^{b}
	14	170	56.75^{a}	33.96^{bc}	60.40^{bc}	9.29^{b}
	21	164	55.71^{b}	34.75^{b}	62.69^{b}	9.54^{a}
	28	166	54.24^{c}	36.17^{a}	67.01^{a}	9.59^{a}
	SEM		0.21	0.20	0.62	0.05
	***p*-value**		***	***	***	***
TF (times/d)	**0**	215	55.95	34.67	62.41	9.39
	1	227	56.07	34.51	62.06	9.42
	24	230	56.10	34.53	61.91	9.37
	SEM		0.18	0.17	0.54	0.05
	***p*-value**		-	-	-	-
EP	**PEU**	227	55.88^{ab}	34.76^{a}	62.63^{ab}	9.36
	BEU	227	55.78^{b}	34.79^{a}	62.89^{a}	9.43
	H	218	56.46^{a}	34.16^{b}	60.85^{b}	9.38
	SEM		0.18	0.17	0.54	0.05
	***p*-value**		*	*	*	-
Interactions				***p*-value**		
SL × TF			*	-	-	-
SL × EP			-	-	-	-
TF × EP			-	-	-	-
SL × TF × EP			-	-	-	-

SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal.

$^{a, b, c}$ Means along the same column with different superscripts are significantly (*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$) different.