

Quality assessment of chukar partridge (*A. chukar*) eggs during different conditions (time, turning and position) of storage

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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 ($p < 0.001$). Internal egg quality traits weren't statistically affected by turning frequency except yolk index ($p < 0.01$). An improvement was observed in Haugh unit, albumen index and height 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°C–20°C and 75%–80% relative humidity [2]. Egg production of partridge eggs was 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

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Availability of data and material

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions

Conceptualization: Çam M.
Data curation: Kaya ZK, Güler S.
Formal analysis: Çam M.
Methodology: Çam M.
Software: Çam M, Kaya ZK, Güler S.
Validation: Kırkçı K.
Investigation: Harman H, Kırkçı K.
Writing - original draft: Çam M, Kaya ZK, Güler S.
Writing - review & editing: Çam M, Kaya ZK, Güler S, Harman H, Kırkçı K.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Selcuk University Faculty of Veterinary Experimental Animals Production and Research Center (Permit No. 2021/58, date of approval: 28.04.2021).

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 one 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 Çağlayan et al. [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 Günhan and Kırkçı [7] stated that the partridge eggs could resist protein degradation in the long-term storage period. The turning of eggs during long storage period was 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 et al. [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 × 1.2 × 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.

Experimental design

Daily fresh chukar eggs were numbered and assigned to three experimental groups 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 four consecutive days according to the storage length. For the forming of three different turning groups, the eggs were set into three same model of storage chambers (HD-960L-3in1) at average 15°C and

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 ¹⁾	0.25
DL-Methionine	0.02
Calculated nutrient concentration	
ME (kcal/kg)	2,800
CP (% KM)	18
Ca (%)	3.11
P (%)	0.61
Lysine (%)	1.5
Methionine + cystine (%)	0.6

¹⁾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.

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 caliper (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 below [13].

- (1) Albumen index (%): $[(\text{Albumen height} / (\text{Albumen length} + \text{Albumen width}) / 2)] \times 100$
- (2) Albumen weight (g): $\text{Egg weight} - (\text{Yolk weight} + \text{Shell weight})$
- (3) Albumen ratio (%): $(\text{Albumen weight} / \text{Egg weight}) \times 100$
- (4) Yolk index (%): $(\text{Yolk height} / \text{Yolk diameter}) \times 100$
- (5) Yolk ratio (%): $(\text{Yolk weight} / \text{Egg weight}) \times 100$
- (6) Yolk / albumen ratio: $(\text{Yolk weight} / \text{Albumen weight}) \times 100$
- (7) Haugh Unit: $100 \log [\text{Albumen height} - (1.7 \times \text{Egg weight}^{0.37}) + 7.57]$
- (8) Shell ratio (%): $(\text{Shell weight} / \text{Egg weight}) \times 100$

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 analyzed by General Linear Model (GLM; SPSS ver. 25.0). Storage length, turning frequency, egg position and their interactions were 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 Tables 2 and 3 respectively. Storage length showed significant effect on almost all quality parameters illustrated in Table 3 ($p < 0.001$). 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 ($p < 0.01$).

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 ($p < 0.001$).

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.

Egg component ratios

Egg component ratios in different storage length, turning frequency and egg position were given in Table 8. The effects of fixed factors were 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.

Interactions between traits

Some significant interactions among factors for all quality traits were observed in the study (Tables 3 and 5). The significant interactions were summarized by interpretation of one-way analysis which

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
7	0	PEU	18	39.46	54.25	4.59	30.10	11.98
		BEU	18	39.34	53.61	4.72	29.87	12.55
		H	17	44.72	62.52	4.42	29.60	12.45
	1	PEU	20	39.44	54.79	5.10	30.09	12.59
		BEU	20	38.58	52.48	4.46	30.13	12.23
		H	19	43.56	60.73	4.05	30.77	12.08
	24	PEU	20	40.22	57.98	4.68	30.40	12.91
		BEU	20	39.58	56.17	4.43	30.45	12.44
		H	20	40.91	54.60	4.67	29.71	12.65
14	0	PEU	16	39.08	58.82	4.85	30.09	13.24
		BEU	17	41.04	57.88	4.48	30.79	12.75
		H	20	40.11	60.34	4.22	30.25	12.63
	1	PEU	19	37.80	54.66	4.43	30.41	12.48
		BEU	20	42.28	61.02	4.39	29.95	13.21
		H	20	39.33	57.69	4.23	30.80	12.53
	24	PEU	20	40.47	56.08	4.44	30.64	13.16
		BEU	20	42.44	59.36	4.47	29.73	13.16
		H	18	41.12	61.53	4.23	30.12	12.74
21	0	PEU	20	40.64	56.58	4.32	31.98	12.47
		BEU	19	40.13	56.87	4.35	30.40	12.65
		H	16	39.91	57.41	4.22	30.77	12.53
	1	PEU	19	39.71	56.74	4.28	31.49	12.21
		BEU	17	39.94	55.57	4.00	31.27	12.47
		H	18	39.33	57.50	4.26	31.03	12.23
	24	PEU	19	40.54	57.10	4.17	30.87	12.35
		BEU	18	40.65	58.60	4.07	31.02	12.66
		H	18	38.63	53.65	4.32	30.89	12.40
28	0	PEU	17	42.13	57.39	4.10	33.54	11.99
		BEU	19	38.06	52.94	4.03	31.30	11.96
		H	18	38.21	57.81	4.13	32.11	12.05
	1	PEU	20	39.69	53.20	4.33	32.77	11.54
		BEU	19	41.15	56.94	4.23	32.08	11.82
		H	16	38.73	54.71	4.16	31.31	12.15
	24	PEU	19	38.71	54.57	4.06	32.12	12.15
		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; AW, albumen width; AL, albumen length; AH, albumen height; YW, yolk width; YH, yolk height; PEU, pointed end up; BEU, blunt end up; H, horizontal.

the raw means of subgroups could be seen in Tables 2 and 4. 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

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		-	***	*	**	*

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

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

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

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
28	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
	1	PEU	20	2.34	35.25	82.67
		BEU	19	2.18	36.85	82.03
		H	16	2.26	38.80	81.36
	24	PEU	19	2.22	37.87	80.56
		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; AI, albumen index; YI, yolk index; HU, Haugh unit; PEU, pointed end up; BEU, blunt end up; H, horizontal.

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 ($p < 0.05$).

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
<i>p</i> -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
<i>p</i> -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
<i>p</i> -value		**	-	**
		Interactions		
		<i>p</i>-value		
SL × TF		-	-	-
SL × EP		***	**	*
TF × EP		***	-	*
SL × TF × EP		*	***	-

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

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.

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 were reported to show an increase with long term storage time [15]. Albumen height and index, yolk index and Haugh unit of chukar eggs decreased significantly as the storage period lengthened which agrees with the findings of rock partridges [6,12]. But most of these decreases were found in the eggs after 21 days of storage period. These results confirmed the study of Günhan and Kırıkçı [7] who found a fluctuation in most of egg quality parameters of rock partridge till 21 days of storage time and then more evident significant differences. The main possible explanation of this result is that partridge eggs are resistant to longer storage duration compared with other poultry species [7,16,17]. Other explanations are that albumen height is one of the measures of the albumen viscosity which plays an important role to obtain sufficient nutrients by the blastoderm in the early period of incubation [18]. Extended storage time caused excessive albumen degradation, the result of which albumen got thinner and

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
28	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
	1	PEU	20	7.37	11.03	1.97
		BEU	19	7.27	11.80	1.95
		H	16	7.25	11.35	2.01
	24	PEU	19	7.51	11.29	1.96
		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.

watery, and therefore caused a decrease in Haugh unit which might cause higher embryonic death in the early period of incubation [19]. Khan et al. [20] reported that prolonged storage period impairs egg quality parameters due to water loss from the eggs. Although yolk diameter and height showed a fluctuation up to 21 days of storage, significant increase for yolk diameter and decrease for its height were observed in the current study. These findings supported the ideas of Kirunda and McKee [21], who reported that weakening vitelline membrane and chalazae caused an increase

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		-	-	-

^{a-c}Means along the same column with different superscripts are significantly (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$) different. SL, storage length; TF, turning frequency; EP, egg position; PEU, pointed end up; BEU, blunt end up; H, horizontal.

in yolk diameter and a decrease in its height during prolonged storage period. When the yolk diameter gets larger with long storage duration, yolks become fragile and eventually tend to mix up with albumen [22].

Chukar egg components weights and their ratios were significantly differed by storage length. Prolonged storage period decreased the albumen weight and increased yolk weight in current study. The differences in these components were based on the move of water from albumen to yolk during the long storage period in relation with changes in the permeability of the vitelline membrane [20]. As for proportions of egg components, while albumen ratio decreased; shell and yolk ratio increased with long-term storage duration. This was mostly related to a loss in albumen weight over time [23]. Findings of rock partridges by Çağlayan et al. [6] and Günhan and Kırıkçı [7] were in agreement with ours. In the current study, significant interaction was observed between storage length and turning frequency only for yolk weight and albumen ratio. Melo et al. [24] found an interaction between eggshell weight of broiler breeders with different storage length and turning frequency but they didn't find any interaction 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 et al. [24] reported that 12 days of holding period had an adverse effect on quality of broiler breeder eggs independent of turning. But they found

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
28	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
	1	PEU	20	54.22	36.13	67.11	9.65
		BEU	19	53.91	36.35	67.80	9.74
		H	16	55.04	35.21	64.13	9.75
	24	PEU	19	54.35	36.22	67.06	9.44
		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.

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

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		-	-	-	-

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

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

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 are 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 et al. [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 et al. [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.

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