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RESEARCH ARTICLE

The Effects of Hen Age, Genotype, Period and Temperature of Storage on Egg Quality

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Summary

This study was planned to investigate the main effects of genotype, hen age, storage temperature, length of storage and their interactions on internal and external quality of table egg. A total of 3840 eggs from commercial ISA Brown (33 to 64 weeks old), and Lohman White (35 to 66 weeks old) hens were stored at 4°C and 24°C from 0 to 5 weeks. Egg weight, egg weight loss, albumen width, albumen height, albumen index, yolk width, yolk height, yolk index, Haugh unit (HU), shell weight, shell thickness, shell density and shell weight per unit surface were examined. Although genotype except egg weight loss, yolk height and shell density, and hen age significaltly affected all the traits were examined in the study, storage temperature and period affected egg weight loss and internal qaulity traits only. Interactions between different factors for egg weight loss and all internal quality traits were significant. It was concluded that internal egg quality loss during the extended storage was dramatic in eggs from Brown lines, laid by younger hens and stored at 24ºC. Therefore, the shell color, the hen age, the storage temperature and period should be taken into consideration during marketing of table eggs.

Keywords: *Genotype, Hen age, Storage time, Storage temperature, Egg quality*

Tavuk Yaşı, Genotip, Depolama Süresi ve Sıcaklığının Yumurta Kalitesine Etkisi

Özet

Bu çalışmada genotip, tavuk sıcaklığı, depolama ısısı, depolama süresi ve bu faktörler arası interaksiyonların iç ve dış yumurta kalitesine etkilerinin belirlenmesi amaçlanmıştır. Araştırma 33-64 haftalık yaşlardaki ISA Brown ve 35-66 haftalık yaşlardaki Lohman White ticari yumurtacı hatlarından elde edilen toplam 3840 yumurtada gerçekleştirilmiştir. Yumurtalar 5 hafta boyunca 4 ve 24ºC sıcaklıklarında depolanmıştır. Yumurta ağırlığı ve ağırlık kaybı, albümin genişliği ve yüksekliği, albümin indeksi, sarı genişliği, sarı yüksekliği, sarı indeksi, Haugh birim, kabuk ağırlığı, kabuk kalınlığı, kabuk yoğunluğu ve birim yüzey alanına düşen kabuk ağırlığı incelenmiştir. Yumurta ağırlık kaybı, sarı yüksekliği ve kabuk yoğunluğu hariç genotip ve tavuk yaşı çalışmada incelenen tüm özellikleri önemli derecede etkilemiş, depolama sıcaklığı ve süresi sadece yumurta ağırlık kaybı ve iç kalite özelliklerini etkilemiştir. Yumurta ağırlık kaybı ve iç kalite özellikleri bakımından incelenen faktörler arası etkileşimlerin önemli olduğu saptanmıştır. Uzayan depolama sırasında yumurta iç kalite kaybı Kahverengi hatların ve genç tavukların yumurtalarında ve 24ºC'de depolanan yumurtalarda çok fazla idi. Bu nedenle, sofralık yumurtaların satışı sırasında kabuk rengi, depolama sıcaklığı ve süresi dikkate alınmalıdır.

Anahtar sözcükler: *Genotip, Tavuk yaşı, Depolama süresi, Depolama sıcaklığı, Yumurta kalitesi*

INTRODUCTION

Faster and effective selection programs in last 50 years gave a rise to the production of high-yielding commercial layer hybrids. The performances and egg characteristics of hens kept in cage systems were almost standardized. However, hen welfare and housing systems exposed to more environmental variations are coming into agenda due to EU regulations starting from the 2000s [1-3].

Due to color of egg may impact on consumer preferences both white and brown egg lines are available to industry today. Though selection realized

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in Brown egg layer were slower then white lines [4-5]. Differences between white and brown egg lines were defined in previous researches [6-14]. However these knowledge must be updated to solve problems of alternative housing systems and genetic improvement programs [3,15].

Albumen height and Haugh unit are reported to be evaluated as indicators of egg freshness and internal quality [16-18]. Silversides and Villeneuve [19] declared that changes in albumen quality during storage are described equally well by albumen height and HU. Age of hen [20-22], storage period [23-26] and temperature [27-30] are separately well defined as the major factors affecting egg quality traits [17,22]. But there are few studies written about the effects of these factors and their interactions [5,7,31]. Determination of interactions will be useful to over-come the low egg quality and security problems in alternative systems and develop more effective improvement programs and housing facilities [3,15].

In this study, it was aimed to determine the effects of genotype, hen age, storage temperature and period on internal and external quality of eggs, and their reveal interactions among different factors.

MATERIAL and METHODS

The experiment was conducted in Department of Animal Husbandry, Faculty of Veterinary Medicine, Afyon Kocatepe University from February to May 2004. A total 3840 eggs were obtained from commercial ISA Brown (33 and 64 weeks old) and Lohman White (35 and 66 weeks old) hens were housed in conventional cages. Eggs were laid in the morning (9.00-10.00 h) on a single day, collected and placed into viols and transported to the laboratory in a closed vehicle.

Eggs were measured within 4 h of being laid (fresh), and after 1, 3 and 5 week storages. Eggs were stored in a room with heater controlled by thermostat (24°C and 70-80 % RH) and industrial type refrigerator (+4°C and 55-60% RH). Air ventilation was obtained by fans in both environments.

At sampling, eggs were weighed and broken by one by one onto a flat surface where the height of inner thick albumen and yolk were measured with the nearest 0.01 mm using a micrometer. Long and short diameters of albumen and diameter of yolk were measured using a digital caliper. The shell was washed with water, holds at room temperature and then dried at 100ºC for 4 h, and weighted. Egg shell thicknesses (at the pointed end, equator and blunt end of egg shells with membrane/3) were measured with the micrometer.

The information on egg weight, egg weight loss, albumen width, albumen height, albumen index, yolk width, yolk height, yolk index, Haugh unit, shell weight, shell thickness, shell density and shell weight per unit surface was collected. The genotypes (Lohman White and ISA Brown), hen ages (33-34 weeks and 64-65 weeks of age), and storage temperature were divided two groups respectively. Storage period were grouped into 4 periods (0 [control], 1, 3, and 5 weeks). Eggs obtained from each genotype and age groups were placed with their blunt end up. There were 120 eggs in each storage period. From the values obtained, the fallowing data were calculated using the formulas written below;

Haugh units = [HU= 100 log (H-1.7W$^{0.37}$ + 7.57)] [18]
Albumen index = yolk height/(long diameter of albumen + short diameter of albumen/2) x100 [16]
Yolk index = yolk height/yolk width x 100 [32]
Shell density = shell weight/3.9782 x egg weighW$^{0.662}$ x shell thickness [33]
Shell weight per unit surface = shell weight /4.835 W3.9782 x egg weight $^{0.7056}$ [34]

The effect of genotype, hen age, storage temperature and period on different traits was analyzed by the method of least-squares using the following model:

$$Y_{ijklm} = \mu + G_i + HA_j + ST_k + SP_l + GHA_{ij} + GST_{ik} + GSP_{il} + HAST_{jk} + HASP_{jl} + STSP_{kl} + e_{ijklm},$$

where,

Y_{ijklm} = the mth observation in the lth storage period, kth storage temperature, jth hen age, and ith genotype;
μ = the over all mean;
G_i = the effect of ith genotype (i=1,2);
HA_j = the effect of jth hen age (j=1,2);
ST_k = the effect of kth storage temperature group (k=1,2);
SP_l = the effect of lth storage period (l=1,….4);
GHA_{ij}, GST_{ik}, GSP_{il}, $HAST_{jk}$, $HASP_{jl}$, $STSP_{kl}$ = two-way interactions between different effects.
e_{ijklm} = random error N(0,σ²).

Data were analyzed by using GLM and Duncan options of SPSS computer program. Interactions for external quality were removed from the model because of inadequate data in subclasses. Also 2-way and 3-way interactions for the egg weight, egg weight loss and internal quality were excluded from the study because of insufficient data in subclasses [35-37].

RESULTS

Effects of hen genotype

The least-squares means for different traits were shown in *Table 1*. The effect of genotype on fresh egg weight was significant (P<0.05). Genotype had no significant effect on weight loss during storage. All internal egg quality traits were significantly (P<0.05) affected by genotype *(Table 2)*. Lower albumen width and yolk index and higher albumen height, albumen index, yolk width and Haugh unit in Brown eggs were found. Thinner shell and lower shell weight were observed in white eggs. The effect of genotype on shell weight per unit surface was not significant.

Effects of hen age

Weights of fresh and stored eggs were different between hen age groups (P<0.01). Older hens laid bigger eggs, but these eggs lost more weight during storage (P<0.01), *Table 1*. Internal quality were significantly (P<0.01) affected by hen age *(Table 2)*. Albumen height, albumen index, yolk height, yolk index, and Haugh unit were higher and albumen and yolk widths were lower in eggs from young hens . Shell thickness decreased and shell weight increased with advancing age in hens (P<0.01) *(Table 3)*. Age had no significant effect on shell weight per unit surface and shell density.

Effect of storage temperature

The temperature of storage environment significantly (P<0.01) affected the egg weights and weight loss during storage period. The eggs stored at 24ºC lost weights more than those stored at cold did *(Table 1)*. Albumen index, yolk width, yolk index and Haugh unit were higher in eggs stored at 4ºC, whereas albumen width were lower (P<0.01) at that temperature *(Table 2)*. External egg quality traits were not affected by storage temperature *(Table 3)*.

Table 1. *Main and interactive effects on egg weight and weight loss*
Tablo 1. *Yumurta ağırlığı ve ağırlık kaybına ana ve interaktif faktörlerin etkisi*

Genotype	Treatments			n	Egg Weight (g)		Weight loss (g)
	Hen age (weeks)	Storage temperature	Storage period (weeks)		Fresh egg	Stored egg	
μ					64.19	62.90	1.30
Lohman White				1880	63.98 ᵇ	62.69 ᵇ	1.29
ISA Brown				1895	64.42 ᵃ	63.10 ᵃ	1.31
	33			1900	62.27 ᵇ	61.03 ᵇ	1.24 ᵇ
	64			1875	66.13 ᵃ	64.77 ᵃ	1.35 ᵃ
		4ºC		1936	64.42	63.88 ᵃ	0.56 ᵇ
		24ºC		1839	63.97	61.91 ᵇ	2.04 ᵃ
			0	960	64.14 ᵃ	64.03 ᵃ	-
			1	952	64.40 ᵃ	63.85 ᵃᵇ	0.89 ᶜ
			3	937	64.44 ᵃ	62.99 ᵃᵇ	1.66 ᵇ
			5	926	63.79 ᵇ	60.73 ᵇ	2.64 ᵃ
ANOVA					**Probability**		
Genotype (G)					*	*	-
Hen age(HA)					**	*	*
Storage temperature (ST)					-	*	**
Storage period(SP)					-	**	**
GxFA					*	-	-
GxST					-	-	*
G x SP					-	-	-
HA x ST					-	-	-
HA x SP					-	-	-
ST x SP					-	*	**
SEM					0.30	0.24	0.08
R^2					0.17	0.16	0.17

a-b Means in a column and treatment variable with no common superscript differ significantly (P<0.05)

Effects of storage period

Effect of storage period were significant (P<0.05) for egg weight after storage and egg weight loss during the storage (P<0.01), *(Table 1)*. Weight loss increased with the advancing storage period. Internal egg quality was significantly (P<0.01) affected by storage time *(Table 2)*. As the storage period elevating, albumen width increased, whereas albumen height, albumen index, yolk width, yolk index and Haugh unit decreased. Shell traits were not affected by storage period *(Table 3)*.

Interactions

All two-way interactions were presented in *Tables 1* and *2*. The interactions between storage temperature and period were significant (P<0.05) for egg weight loss *(Table 1)*. Eggs lost more weight when they were stored at room temperature than that of cold storage *(Fig 1)*.

G x HA interactions for albumen width and height, albumen index and Haugh unit and G x ST interactions for albumen height, yolk index, and Haugh unit were significant (P<0.05). The significant (P<0.05) effects of G x SP and HA x SP interactions for internal quality (except yolk diameter) were determined. In addition, HA x ST interactions for yolk index and Haugh unit and SP x ST interactions for all internal quality were also significant (P<0.05).

G x HA, G x ST and G x SP interactions showed that white and brown eggs lost internal quality with increasing storage period. But this loss was more in eggs being laid by brown line hens *(Fig 2)*. The relationships between hen age and temperature, and hen age and storage period stated that egg quality losses during extended storage at room temperature of egg from younger hens were decreased more rapidly *(Fig 3)*. Significant (P<0.05) SP x ST interaction indicated that Haugh unit in eggs stored at higher temperatures decreased dramatically *(Fig 4)*.

Table 2. *Main and interactive effects on internal egg quality traits*
Tablo 2. *Yumurta iç kalite özelliklerine ana ve interaktif faktörlerin etkisi*

Genotype	Treatments			n	Albumen			Yolk			Haugh unit
	Hen age (weeks)	Storage temperature	Storage period (weeks)		Width (mm)	Height (mm)	Index	Width (mm)	Height (mm)	Index	
μ					87.9	3.86	0.05	36.6	62.90	0.485	82.82
Lohman White				1880	82.4 ᵇ	4.07 ᵃ	0.05 ᵃ	37.1 ᵃ	62.69	0.478 ᵇ	85.92 ᵃ
ISA Brown				1895	93.4 ᵃ	3.66 ᵇ	0.04 ᵇ	36.1 ᵇ	63.10	0.492 ᵃ	79.72 ᵇ
	33			1900	87.2 ᵇ	3.92 ᵃ	0.05 ᵃ	35.6 ᵃ	61.01 ᵇ	0.490 ᵃ	83.27 ᵃ
	64			1875	88.6 ᵃ	3.81 ᵇ	0.04 ᵇ	37.7 ᵇ	64.77 ᵃ	0.480 ᵇ	82.37 ᵇ
		4°C		1936	80.8 ᵇ	4.05 ᵃ	0.05 ᵃ	36.1 ᵃ	63.88 ᵃ	0.551 ᵃ	87.62 ᵃ
		24°C		1839	95.1 ᵃ	3.68 ᵇ	0.04 ᵇ	34.9 ᵇ	61.91 ᵇ	0.420 ᵇ	78.02 ᵇ
			0	960	77.3 ᶜ	4.81 ᵃ	0.07 ᵃ	37.8 ᵃ	64.03 ᵃ	0.529 ᵃ	92.89 ᵃ
			1	952	87.3 ᵇ	4.37 ᵃ	0.06 ᵇ	37.2 ᵃ	63.85 ᵃ	0.484 ᵇ	91.25 ᵃ
			3	937	92.1 ᵇ	3.23 ᵇ	0.05 ᵇ	35.5 ᵇ	62.99 ᵇ	0.473 ᶜ	73.76 ᵇ
			5	926	95.1 ᵃ	3.04 ᶜ	0.04 ᶜ	35.7 ᵇ	60.72 ᶜ	0.455 ᵈ	73.39 ᵇ
ANOVA					Probability						
Genotype (G)					**	**	**	**	-	**	**
Hen age(HA)					**	*	*	**	**	**	**
Storage temp. (ST)					**	*	**	**	**	**	**
Storage period (SP)					**	**	**	**	**	**	**
GxFA					**	**	**	-	**	-	**
GxST					-	**	**	-	**	**	*
G x SP					**	**	**	-	*	**	**
HA x ST					-	-	-	-	**	**	*
HA x SP					*	**	**	-	**	**	**
ST x SP					**	**	**	**	**	**	**
SEM					0.07	0.06	0.06	0.04	0.29	0.00	0.75
R^2					0.45	0.48	0.48	0.10	0.17	0.47	0.48

a-d Means in a column and treatment variable with no common superscript differ significantly (P<0.05)

Table 3. *Main and interactive effects on external egg quality traits*
Tablo 3. *Yumurta dış kalite özelliklerine ana ve interaktif faktörlerin etkisi*

Genotype	Treatments			n	Egg Shell			Shell weight per unit surface (g/cm²)
	Hen age (weeks)	Storage temperature	Storage period (weeks)		Weight (g)	Thickness (mm)	Density (g/cm³)	
μ					6.02	40.12	0.327	81.43
Lohman White				480	5.96 b	39.58	0.324	81.80
ISA Brown				480	6.07 a	40.66	0.331	81.07
	33			480	5.90 b	40.78	0.332 a	81.30 b
	64			480	6.13 a	39.46	0.323 b	81.57 a
		4 ºC		480	5.98	39.98	0.327	79.43
		24ºC		480	6.06	40.27	0.328	81.44
			0	240	5.99	40.41	0.329	81.34
			1	240	6.04	40.02	0.328	81.68
			3	240	6.07	39.90	0.326	81.63
			5	240	5.97	40.15	0.326	81.10
ANOVA							**Probability**	
Genotype (G)					*	**	-	-
Hen age(HA)					**	**	*	*
Storage temp. (ST)					-	-	-	-
Storage period (SP)					-	-	-	-
SEM					0.02	0.23	0.00	0.28
R^2					0.10	0.13	0.16	0.02

a-b Means in a column and treatment variable with no common superscript differ significantly (P<0.05)

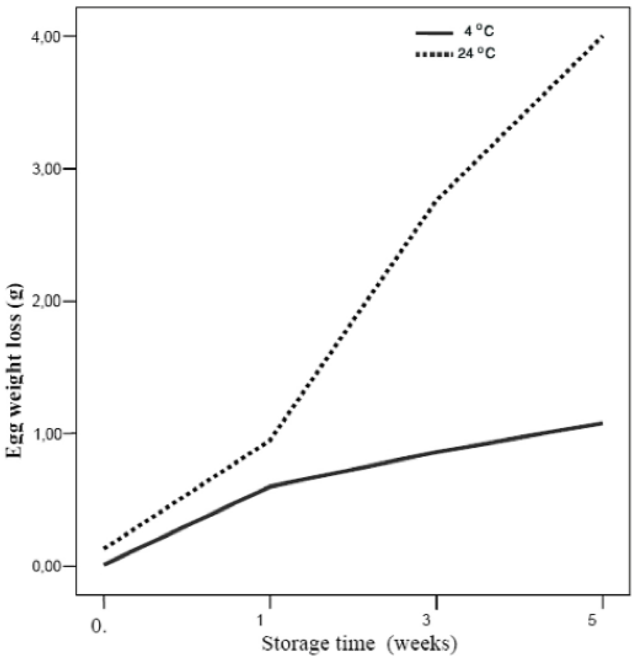

Fig 1. Effect of storage temperature x storage period on egg weight loss

Şekil 1. Yumurta ağırlık kaybına depolama sıcaklığı x depolama süresi interaksiyonunun etkisi

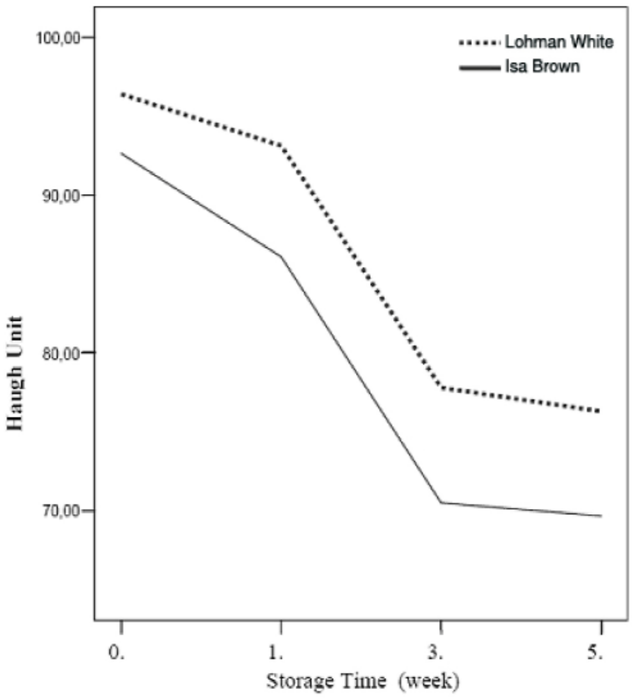

Fig 2. Effect of genotype x storage period on Haugh units

Şekil 2. Hauhg birime genotip x depolama süresi interaksiyonunun etkisi

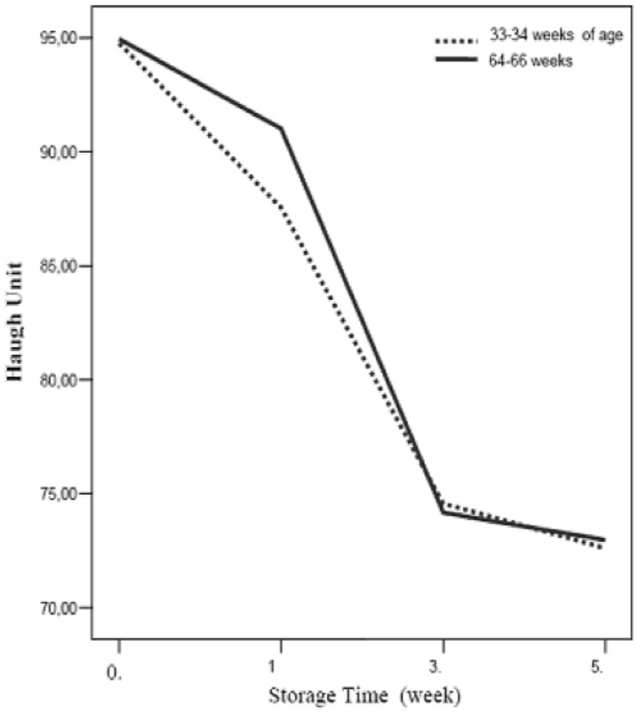

Fig 3. Effect of hen age x storage period on Haugh units

Şekil 3. Hauhg birime genotip x depolama süresi interaksiyonunun etkisi

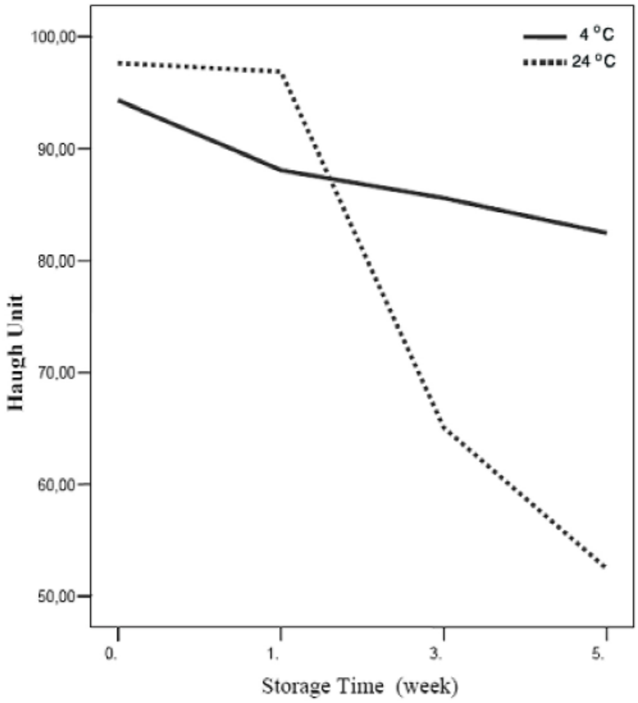

Fig 4. Effect of storage temperature x storage period on Haugh units

Şekil 4. Hauhg birime depolama sıcaklığı x depolama süresi interaksiyonunun etkisi

DISCUSSION

Keener et al.[29], Washburn [9], Poggenpoel [22] and Scott and Silversides [5] reported that brown egg layers laid are weighty than white layers and lay heavier eggs than white layer. Similar results were found in this study. These diversifications can be derived from the differences among the genotypes.

Significant effect of genotype on inner quality of eggs was consonance with the findings of Petersen [11]. Albumen figure and thickness which shows the quality of albumen were affected by the factor before laying [5,33]. Brown eggs were heavier. They had also thicker shell, higher albumen and lower yolk. These results are in tune with those of Silversides and Scott [7] and Scott and Silversides [5]. Haugh unit increased in whites and decreased in browns with increasing ages ($P<0.05$). This unit dropped and albumen height raised in brown layers with increasing storage period, these results are agree with the findings of Silversides and Budgell [31]. But the reason of increasing HU in whites can not be explained.

As expected, the egg weights increased with age [20,21,31]. Willams [17] reported that the age were most significant factors affecting albumen quality. The eggs being laid by the old hens lost more weight during storage. Aging and thinning of eggshells in old hens may result in this finding. Britton [12] and Peebles and Brake [13] announced that older hens produce eggs with thinner shells and shorter pores than young hens and these short pores might make albumen lose water. Hen age significantly ($P<0.05$) affected the internal quality traits. These traits were higher in the eggs form older hens. Silversides and Scott [7], Cunningham [21] and Silversides and Budgel [31] reported that albumen height decreased with increasing hen age. The egg shell thickness declined ($P<0.01$) and shell weight increased ($P<0.01$) in the eggs from older hens. Shell weight findings of this study were similar to the findings (5.79 and 6.13 g for ISA-White and ISA-Brown eggs respectively) of Scott and Silversides [5]. Eggs stored at room temperature lost excessive weight and internal quality. These losses were lower in eggs stored at refrigerator at same periods. In similar way, Heath [20] reported that the weight of vitellin membrane increased at refrigerator temperature. Jones and Musgrove [23] also declared that the cold storage up to 30 days would not decrease the internal quality of eggs. These results were expected due to storage temperature increases the loss of water and CO_2 and inevitable result of this phenomenon is the decrease in albumen pH. Thick albumen gets thinner and liquid and protein passing from albumen to yolk increases by declination in vitellin membrane resistance [6,14,26]. In this research, HU value of eggs stored in refrigerator up to 5 weeks, 9 unit higher than those stored in room temperature at the same time. This finding indicated that the shelf life of commercial eggs could be escalated without more loss in quality. External quality traits were not affected by storage temperature *(Table 3)*. This result is expected because the egg shell has a calcium carbonate structure, hence it is not expected to change by environmental temperatures [11,13,31]. Why internal egg quality looses during extended storage at room temperature of the egg from younger hens were decreased more rapidly was not explained exactly but the productivity of these younger hens is high and this may result in decrease in egg shell strength. So it might be thought that eggs lost water and CO_2 more rapidly [14,17]. Oosterwoud [24] similarly reported that a significant negative correlation between egg shell strength and hen productivity.

Longer stored eggs lost more weight. This finding is in accordance with the results of Jones and Musgrove [23]. Haugh Unit values decreased with increasing storage period. This can be originated from the lost of liquid part of albumen during storage [11,19,25-27]. Keener et al.[29] reported that albumen height and HU unit decreased with longer storage time. Jones and Musgrove [23] reported that the albumen height and Haugh unit were decreased from 7.05 mm and 82.59 to 4.85 mm and 67.43 respectively at the end of 10 weeks storage. In this study, the Haugh unit decreased from 91.25 to 73.39 in eggs stored for 5 weeks. Storage time had no effect on shell traits and Silversides and Budgell [31] reported similar results.

Significant interactions among genotype, hen age, storage temperature and storage time were determined in this study. Scott and Silversides [5] reported that there was significant correlation between storage period and genotype for albumen height. Silversides and Budgell [31] reported that the hen age x genotype interactions were significant for shell, albumen and yolk components. These interactions indicated that the egg could show different reactions to different environmental effects due to its genotype at storage needed for market conditions [5,9,10]. Some factors such as genotype, hen age, storage temperature and period significantly influence the quality of egg.

The results of this study indicated that egg quality was affected by genotype and age of hen. Inner egg quality was higher in eggs from young Brown laying hens. Genotype x hen age, genotype x storage temperature and genotype x storage time interactions showed that internal egg quality loss during the extended storage was dramatic in eggs from Brown lines, laid by younger hens and stored at 24°C.

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