Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X 2020 / v.22 / n.4 / 001-010

http://dx.doi.org/10.1590/1806-9061-2020-1331

Original Article

Assessment of Egg Quality in Native and Foreign Laying Hybrids Reared in Different Cage Densities

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■Keywords

Age, Atak-S, Cage density, Egg quality, Laying hens.

Submitted: 01/June/2020
Approved: 10/July/2020

ABSTRACT

This study aimed to compare the eggs of the native-Turkish Atak-S (A-S) hybrid and the foreign brown layer Isa Brown (IB) and white layer Novogen White (NW) hybrids reared in two different cage densities (468.75 cm^2/hen and 312.50 cm^2/hen) in terms of the internal and external quality parameters of the eggs. A total of 540 hens including 180 from each genotype were used. To determine the egg quality characteristics, one randomly selected egg was taken out of each cage every 4 weeks in the yield period of 24-68 weeks, and analysis were carried out. A total of 648 eggs were used. In the study, the effect of genotype on all parameters was found to be significant. The shell thickness, Haugh unit and albumen index were lower in the Atak-S hybrid. In the white laying hens, the Haugh unit, albumen index and eggshell destruction strength values were higher, while the meat and blood spots and yolk color values were lower. Cage density did not create a significant effect on any parameter except for the blood and meat spot ratio. Age has a significant effect on the egg weight, shape index, Haugh unit, albumen index and yolk index. Consequently, as the native hybrid had similar destruction strength values to the others despite its lower shell thickness, and it had a Haugh unit showing good quality based on the food codex despite lower values than the others, it was concluded that it could compete with the foreign hybrids in terms of egg quality.

INTRODUCTION

Development and protection of domestic gene sources are important in terms of biological diversity, achievement of continuity in animal production and reduction of foreign dependency in obtaining breeding stock material. In the 2016-2020 Master Plan of the Agricultural Research and Policies General Directorate of the Ministry of Agriculture and Forestry, the strategic objective is to achieve food safety and develop methods and technologies to increase yield and quality in production. In this context, the goal of the program is to conduct efforts towards providing breeding stock from domestic sources in laying and broiler hen breeding and creating suitable nutrition and breeding methods for this. For this reason, one should carefully examine the breeding and feeding techniques of native hybrids, biotechnological methods, effects of environmental factors and yields in private sector conditions (Ministry of Agriculture and Forestry, 2020).

Turkey is among the leading countries in the world in commercial egg production, and approximately 2.5% of the hens used in egg production consist of native laying hybrids (Kamanlı *et al.*, 2016). As a result of the work carried out in 1995 for the purpose of production of native laying hybrids, there are 3 native laying hybrids today. Among these hens, Atak-S has come to a level to compete with foreign commercial hybrids with its adaptation capacity to environmental conditions, egg yield and egg weight characteristics, and it has become a hen preferred by breeders (Türkoglu & Sarıca, 2014).

For poultry that are sensitive to environmental conditions, poultry houses are an indispensable breeding element. To meet the optimum environment needs and achieve sustainability with the lowest cost, types of housing and breeding systems have great importance. Despite the negative effects of high housing density in laying hens on production performance, producers think of obtaining the maximum benefit from a unit area and economically increase their income by increasing the number of animals per cage (Dawkins *et al*., 2004).

Eggs, which have a high biological value and increase growth, are of great importance in nutrition, especially in the growth of infants and children and in the nutrition of people of all ages regarding the low calories and high biological utilization rates for patients and people in diets as a product that cannot be manipulated due to its natural structure (Surai & Fisinin, 2015). In addition to the biological significance of eggs in nutrition, their easily accessible and inexpensive nature has led their consumption to increase through the years. In Turkey, the per capita egg consumption for 2018 was determined as 224 eggs annually, while this number has increased in recent years (Yum-Bir, 2020). Today, there is a trend of demand for healthier products by consumers. Quality in the food industry may be expressed as the entirety of characteristics that affect consumer preferences. Factors that concern consumers are stated as the egg's size, cleanliness, freshness, nutritional value, color, rigidity and taste (Yılmaz Dikmen *et al*., 2017; Akkuş, 2016; Samiullah *et al*., 2014). In this sense, one of the main goals of the egg industry is to produce high-quality eggs and distribute them to the consumer. The determination of egg quality characteristics depends on several factors before and after laying. Factors that influence egg quality may be listed as genotype, age, live weight, breeding systems, health, nutrition, stress and housing (Onbaşılar *et al*., 2018; Yıldız *et al*., 2013; Petricevic *et al*., 2017; Lordelo *et al*., 2020; Onbaşılar &Tabib, 2019; Göger, 2019; Ahmad *et al*., 2019; Petek *et al*., 2009).

This study aimed to compare the eggs of the Native-Turkish Atak-S (A-S) hybrid, foreign brown layer Isa Brown (IB) and white layer Novogen White (NW) hybrids reared in two different cage densities in terms of the internal and external quality parameters of the eggs.

MATERIAL AND METHODS

The study design was approved by the Local Ethics Board for Experimental Animals of Atatürk University, on the basis of their Decision Number 156, which was taken at their seventh session dated 04.11.2016 and notified in their official letter dated 36643897-000-E.1600261813. The study was carried out at the Laying Hen House at the Poultry Unit of the Food and Animal Husbandry Research and Application Center of Atatürk University. In the poultry house, a 3-storey battery cage system was present. Each cage unit had the same dimensions, while the depth: 60 cm, width: 62.5 cm, rear height: 46 cm, front height: 51 cm, and feeder length was 62.5 cm. Each cage unit had 2 water nipple systems.

Ventilation was achieved by the windows found on the side walls of the housing, ventilation chimneys on the ceiling and one 140 cm x 140 cm electrical fan working on the principle of negative pressure. The in-house temperature was kept at 16-24 °C with sensors connected to the ventilation and heating systems. Lighting was managed by fluorescent bulbs providing white light. The lighting program was kept as 23 hours of light and 1 hour of dark in the first 3 days in the growth period, 18 hours of light and 6 hours of dark on the 3rd-7th days, 14 hours of light and 10 hours of dark on the 7th-10th days, and 13 hours of light and 11 hours of dark per day from this date to the age of 19 weeks. After 19 weeks of age, the daily time of lighting was increased by 30 minutes each week. From the 27th week where the daily time of light reached 17 hours, the lighting time was kept constant till the end of the yield period.

In this study, NW, IB and A-S hybrids with the same hatching day in November, grown in a ground-type housing in the same breeding establishment were used. 540 hens at the age of 16 weeks, were brought to the research center and were weighed and placed into numbered egg cages. The uniformities of the selected hybrids were determined as 97.50, 96.66 and 97.50% for IB, A-S and NW, respectively.

For the pullets placed into cages, the animals were given a starter feed (2750 kcal/kg metabolizable energy (ME) - 17.50% crude protein (CP)) between weeks 16-20; 2750 kcal/kg ME - 16.26% CP 21-45 weeks , 2720 ME kcal/kg - 15.83% CP 46-65 weeks, and 2720 ME kcal/kg - 15.65% CP until the end of the trial, in granulated form and ad libitum. (Table 1).

In the trial, a system of 3 different hybrids (A-S, NW and IB) and 2 different cage housing densities were created. Normal cage density (NCD) and high cage

Table 1 – The Composition of the Feeds provided to the Hens During the Laying Period.

Ingredients %	17-20 age (weeks)	21-45 age (weeks)	46-65 age (weeks)	66-72 age (weeks)
M. Energy (Kcal/kg)	2750	2750	2720	2720
Crude protein	17.50	16.26	15.83	15.65
Calcium	2.00	3.57	3.74	3.83
Phosphorus	0.65	0.52	0.47	0.41
Phosphorus(Diges.)	0.45	0.37	0.33	0.29
Sodium	0.16	0.15	0.15	0.15
Clorid	0.16	0.15	0.15	0.15
Lysine	0.85	0.76	0.74	0.70
Diges. Lysine	0.70	0.62	0.61	0.57
Methionine	0.36	0.38	0.35	0.33
Diges. Methionine	0.29	0.31	0.29	0.27
Meth./Cysteine	0.68	0.70	0.64	0.61
Diges. M/C	0.56	0.57	0.53	0.50
Tryptophan	0.20	0.19	0.17	0.17
Diges. Tryptophan	-	0.15	0.14	0.14
Threonine	0.60	0.56	0.52	0.52
Diges. Threonine	-	0.45	0.42	0.42
Linoleic Acid	1.00	1.74	1.39	1.13

density (HCD) were organized respectively as 8 hens/cage and 12 hens/cage. A total of 540 hens including 180 from each hybrid were used, and each hybrid group was divided into subgroups with 9 replicates including 8 and 12 animals in each cage (NCD: 468.75 cm^2/hen and HCD: 312.50 cm^2/hen). The animals were randomly distributed into the cages.

To determine the egg quality characteristics, one randomly selected egg from each cage was collected every 4 weeks in the yield period of 24-68 weeks (a total of 54 eggs), and analyses were conducted after keeping the collected eggs at room temperature for 24 hours at the laboratory of the Department of Zootechnics at the Faculty of Veterinary Medicine. For the eggs that were weighed at first, the shape index and eggshell destruction strength were determined, and afterwards, the eggs were cracked onto a glass tray and left for 10 minutes for the other measurements. After the cracking procedure, respectively the yolk color, meat and blood spot determination, yolk diameter, albumen length, albumen width, yolk height, albumen height and shell thickness values were determined and recorded.

Egg Weight: Determined by weighing the eggs on a precision scale with a sensitivity of 0.001 g.

Shape Index: Determined by the index measurement device developed by Rauch. The index measurement refers to the ratio between the width and length of the egg.

Eggshell destruction strength (kg/cm^2): Determined by the measurement device developed by Rauch (1965). The egg was placed horizontally into the measurement tool, force was applied, and the value where the egg cracked was measured as kg/cm^2.

Shell Thickness (mm): Specimens were collected from the blunt, middle and pointy parts of the eggs, and after removing the membranes, shell thickness was determined by a micrometer. The average of these three values was recorded as a single thickness value.

Yolk Color Determination: Carried out in the same lighting conditions and by the same person based on a color scale of a commercial firm (ROCHE) containing different shades of yellow from 1 to 15 based on the standard colorimetric system (CIE).

Blood and Meat Spots: Blood and meat spots observed in the egg albumens and yolks were recorded as present-absent in percentage.

Albumen Index: The albumen width and albumen length were measured with the help of a digital caliper. To determine the albumen height, a Mitutuya brand three-legged micrometer with a sensitivity of 1/100 mm was used. The albumen index was calculated by using the formula below.

Albumen index = [Albumen height / (Average of albumen length and width)] x 100

Yolk Index: The yolk diameter of the eggs was measured by using a digital caliper. To determine the yolk height, a Mitutuya brand three-legged micrometer with a sensitivity of 1/100 mm was used. The yolk index was calculated by using the formula below.

Yolk index = (Yolk height / yolk diameter) x 100

Haugh Unit: To determine the Haugh unit, the egg weight and egg albumen height were determined, and the index was calculated with the formula below.

$$\text{Haugh Unit} = 100 \log (H + 7.57 - 1.7 \times W^{0,37})$$

H =Egg albumen height (mm); W = Egg weight (g)

Statistical Analysis

In the analytical and descriptive analyses of the data obtained from the study, the IBM®SPSS v. 20 package software was used.

In the obtained data, to examine the time-dependent effect in the interval of 24-68 weeks, repeated-measurements analysis of variance was used. The mathematical model was applied in the form of $Y_{ijkl} = \mu + a_i + b_j + z_k + ab_{ij} + e_{ijkl}$. For the data, the General Linear Model (GLM) was used for the age periods of 24-28, 32-36, 40-44, 48-52, 56-60 and 64-68 weeks, whereas the mathematical model in detail with statistical notation was as follows:

$Y_{ijk} = \mu + a_i + b_j + ab_{ij} + e_{ijk}$.

In the model:

Y_{ijkl} = The value of any of the egg quality parameters

μ = Population mean,

a_i = Hybrid effect (IB, A-S, NW)

b_j = Cage density effect (NCD and HCD)

z_k = Week effect (24-68 weeks)

ab_{ij} = Hybrid (i) and cage density (j) interaction

e_{ijkl} = Chance-based error with a mean of 0 and variance of σ^2_e ($N \sim (0, \sigma^2_e)$).

Logistic regression analysis was conducted for the blood and meat spot data, and the applied mathematical model is given below.

$P(y) = (1+e^{(\beta_0+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3)})^{-1}$

In the model:

P(y) = Presence (1) or absence (0) of blood and meat spots,

B_0 = Regression coefficient of the constant,

X_1 = Hybrid effect (IB, A-S, NW)

B_1 = Regression coefficient of the hybrid,

X_2 = Cage density effect (NCD and HCD)

B_2 = Regression coefficient of the cage density,

X_3 = Age effect (24-68 weeks)

B_3 = Regression coefficient of the age.

RESULTS

The data on the external egg quality characteristics obtained from the groups are shown in Tables 2 and 3, those on the internal egg quality characteristics are shown in Tables 4 and 5, and those on blood and meat spots are shown in Table 6. The difference among the hybrids was found significant in all parameters ($p<0.01$). No significant difference was found between the cage density groups in terms of all internal and external egg quality parameters except for the blood and meat spots ($p>0.05$). Similarly, the effect of the interaction of hybrid and density was not found significant for any parameter ($p>0.05$). There were significant differences in the egg weight, shape index, albumen index, yolk index and Haugh unit values based on age in a linear relationship ($p<0.01$).

DISCUSSION AND CONCLUSION

In this study, the effects of the genotype on all parameters were found to be significant. The mean egg weights of the IB, A-S and NW hybrids were found respectively as 63.13, 62.11 and 61.20 g ($p<0.01$). While the desired egg weight values for hatching eggs are 52-70 g, larger eggs are preferred for consumption as food due to their economic significance (Türkoglu & Sarıca, 2014). The high heritability of egg weight (0.4-0.6) may explain the differences among the hybrids in terms of egg weight (Türkoglu & Sarıca, 2014; Göger, 2019). The low egg weight of the NW hybrid may be explained by the fact that white laying hens are in a lighter breed class in terms of live weight, and they have lower feed consumption. The shape index values of the IB, A-S and NW hybrids were determined respectively as 77.65, 74.60 and 74.64 ($p<0.001$). It is known that the unique shape of an egg is determined by different hybrid genotypes in relation to the pushing power of the muscles found in the oviduct area. The dependence of the shape of an egg to the anatomical structure of hens and that especially the pelvic bone shape affects egg formation confirm this situation. In terms of the mean shape index values, the eggs of the A-S and NW hybrids were determined to be the ideal shape for the commercial egg sector (between 72 and 76) (Türkoglu & Sarıca, 2014). Additionally, the high eggshell thickness of the IB hybrid may suggest that there is a positive relationship between shell thickness and the shape index, and the high shell thickness may have affected the shape index value (Kamanlı & Türkoğlu, 2018).The eggshell destruction strength values of the IB, A-S and NW hybrids were found respectively as 1.75, 1.62 and 2.11 kg/cm^2 ($p<0.001$). It may be stated that the difference observed in this study was caused by genetic structures and the differences seen in the calcium metabolism of the animals (Onbaşılar &Tabib, 2019). Moreover, eggshell destruction strength may also be associated with shell thickness. In this study the lowest shell thickness was determined in the A-S hybrid, the lowest eggshell destruction strength was also in A-S. In disagreement to this finding, although the eggshell from the IB hybrid was thicker than that from the NW hybrid, the rounder shape of the egg

Table 2 – Mean and Standard Error Results on External Egg Quality Parameters for Different Age Periods (24-68 weeks).

HYBRİD	CAGE DENSİTY	AGE (week)	EGG WEIGHT (g)	SHAPE INDEX (%)	EGGSHELL DESTRUCTİON STRENGTH (kg/cm^2)	SHELL THICKNESS (mm)
IB	NCD	24-28	56.92±1.02	79.56±0.53	2.10±0.19	0.376±0.007
		32-36	59.79±0.94	79.44±0.53	1.38±0.14	0.394±0.009
		40-44	62.34±1.47	77.44±0.51	1.55±0.16	0.368±0.007
		48-52	63.71±1.23	77.39±0.60	2.01±0.15	0.376±0.009
		56-60	66.30±1.21	77.78±0.63	1.93±0.15	0.381±0.006
		64-68	66.07±1.12	75.72±0.71	1.58±0.12	0.382±0.009
		Mean	62.52±0.55	77.89±0.27	1.76±0.07	0.380±0.004
	HCD	24-28	57.53±1.02	77.89±0.53	1.98±0.19	0.369±0.007
		32-36	61.44±0.94	77.67±0.53	1.47±0.14	0.387±0.009
		40-44	63.96±1.47	78.22±0.51	1.73±0.16	0.364±0.007
		48-52	62.51±1.23	77.56±0.60	1.97±0.15	0.372±0.009
		56-60	69.44±1.21	77.00±0.63	1.62±0.15	0.379±0.006
		64-68	67.57±1.12	76.11±0.71	1.71±0.12	0.386±0.009
		Mean	63.74±0.55	77.41±0.27	1.74±0.07	0.376±0.004
	IB		63.13±0.39^a	77.65±0.19^a	1.75±0.05^b	0.378±0.003^a
A-S	NCD	24-28	56.40±1.02	75.72±0.53	1.54±0.19	0.348±0.007
		32-36	58.04±0.94	74.61±0.53	1.30±0.14	0.352±0.009
		40-44	61.00±1.47	74.39±0.51	1.48±0.16	0.336±0.007
		48-52	63.52±1.23	74.39±0.60	2.02±0.15	0.344±0.009
		56-60	65.64±1.21	73.56±0.63	1.94±0.15	0.356±0.006
		64-68	65.43±1.12	73.44±0.71	1.50±0.12	0.341±0.009
		Mean	61.67±0.55	74.35±0.27	1.63±0.07	0.346±0.004
	HCD	24-28	56.27±1.02	76.33±0.53	2.02±0.19	0.347±0.007
		32-36	57.73±0.94	75.89±0.53	1.22±0.14	0.349±0.009
		40-44	59.70±1.47	73.44±0.51	1.52±0.16	0.343±0.007
		48-52	64.86±1.23	74.72±0.60	1.91±0.15	0.348±0.009
		56-60	67.51±1.21	74.67±0.63	1.70±0.15	0.355±0.006
		64-68	69.18±1.12	74.00±0.71	1.34±0.12	0.343±0.009
		Mean	62.54±0.55	74.84±0.27	1.62±0.07	0.347±0.004
	A-S		62.11±0.39^{ab}	74.60±0.19^b	1.62±0.05^b	0.347±0.003^c
NW	NCD	24-28	56.15±1.02	76.39±0.53	2.53±0.19	0.373±0.007
		32-36	58.13±0.94	75.83±0.53	1.87±0.14	0.377±0.009
		40-44	61.03±1.47	75.11±0.51	1.86±0.16	0.362±0.007
		48-52	63.37±1.23	74.67±0.60	2.65±0.15	0.378±0.009
		56-60	64.52±1.21	73.33±0.63	2.39±0.15	0.371±0.006
		64-68	67.58±1.12	73.11±0.71	1.64±0.12	0.362±0.009
		Mean	61.80±0.55	74.74±0.27	2.16±0.07	0.370±0.004
	HCD	24-28	54.71±1.02	74.94±0.53	2.30±0.19	0.372±0.007
		32-36	55.46±0.94	74.56±0.53	1.55±0.14	0.367±0.009
		40-44	61.56±1.47	74.39±0.51	2.12±0.16	0.371±0.007
		48-52	61.43±1.23	74.94±0.60	2.79±0.15	0.373±0.009
		56-60	64.56±1.21	74.50±0.63	2.02±0.15	0.372±0.006
		64-68	65.85±1.12	73.94±0.71	1.56±0.12	0.364±0.009
		Mean	60.59±0.55	74.55±0.27	2.06±0.07	0.370±0.004
	NW		61.20±0.39^b	74.64±0.19^b	2.11±0.05^a	0.370±0.003^b

$^{a-c}$: Differences between means with different letters on the same column are significant (p<0.001).

IB:Isa Brown, A-S: Atak-S, NW: Novogen White, NCD: Normal cage density, HCD: High cage density.

Table 3 – Effects of Hybrid, Cage Density and Age on External Egg Quality Parameters (*p* value).

GROUP		EGG WEIGHT	SHAPE INDEX	EGGSHELL DESTRUCTİON STRENGTH	SHELL THICKNESS
Hybrid		0.003	0.000	0.000	0.000
Density		0.516	0.782	0.486	0.770
Hybrid x Density		0.066	0.193	0.790	0.832
Age*	Linear	0.000	0.000	0.229	0.871
	Quadratic	0.066	0.979	0.084	0.883

*: Repeated-measures analysis of variance results based on time in the interval of 24-68 weeks.

Table 4 – Mean and Standard Error Results on Internal Egg Quality Parameters for Different Age Periods (24-68).

HYBRİD	CAGE DENSİTY	AGE (week)	YOLK COLOR	HAUGH UNIT	ALBUMEN INDEX	YOLK INDEX
IB	NCD	24-28	11.72±0.41	91.90±1.08	11.45±0.36	46.83±0.69
		32-36	11.50±0.48	90.34±1.13	10.93±0.35	44.18±0.64
		40-44	10.67±0.37	86.42±1.52	9.81±0.42	42.72±0.55
		48-52	11.11±0.44	86.18±1.18	9.73±0.33	41.84±0.53
		56-60	11.56±0.40	80.51±1.32	8.19±0.31	40.66±0.53
		64-68	10.44±0.37	75.26±1.68	7.13±0.31	40.20±0.54
		Mean	11.17±0.18	85.10±0.62	9.54±0.17	42.74±0.25
	HCD	24-28	11.72±0.41	92.94±1.08	11.85±0.36	46.16±0.69
		32-36	12.00±0.48	89.54±1.13	10.69±0.35	43.63±0.64
		40-44	11.28±0.37	85.19±1.52	9.62±0.42	42.44±0.55
		48-52	11.72±0.44	87.37±1.18	10.12±0.33	41.03±0.53
		56-60	12.28±0.40	79.65±1.32	8.15±0.31	39.88±0.53
		64-68	11.67±0.37	74.98±1.68	7.31±0.31	40.59±0.54
		Mean	11.78±0.18	84.95±0.62	9.62±0.17	42.29±0.25
	IB		11.47±0.13[a]	85.02±0.44[b]	9.58±0.12[b]	42.51±0.18[a]
A-S	NCD	24-28	10.94±0.41	89.42±1.08	10.59±0.36	46.09±0.69
		32-36	10.50±0.48	86.40±1.13	9.60±0.35	41.91±0.64
		40-44	11.06±0.37	82.84±1.52	8.64±0.42	41.37±0.55
		48-52	10.56±0.44	82.77±1.18	8.53±0.33	39.60±0.53
		56-60	11.67±0.40	77.63±1.32	7.61±0.31	39.19±0.53
		64-68	10.56±0.37	71.78±1.68	6.52±0.31	38.90±0.54
		Mean	10.88±0.18	81.81±0.62	8.58±0.17	41.18±0.25
	HCD	24-28	11.44±0.41	90.68±1.08	11.06±0.36	46.71±0.69
		32-36	10.72±0.48	87.30±1.13	9.75±0.35	42.62±0.64
		40-44	10.33±0.37	81.79±1.52	8.48±0.42	41.13±0.55
		48-52	10.72±0.44	83.54±1.18	9.12±0.33	41.69±0.53
		56-60	11.67±0.40	76.88±1.32	7.54±0.31	39.20±0.53
		64-68	10.94±0.37	71.84±1.68	6.54±0.31	39.49±0.54
		Mean	10.97±0.18	82.00±0.62	8.75±0.17	41.81±0.25
	A-S		10.93±0.13[b]	81.91±0.44[c]	8.67±0.12[c]	41.49±0.18[b]
NW	NCD	24-28	10.50±0.41	93.91±1.08	11.98±0.36	47.32±0.69
		32-36	8.78±0.48	91.86±1.13	11.47±0.35	44.21±0.64
		40-44	9.83±0.37	88.84±1.52	10.20±0.42	41.09±0.55
		48-52	8.89±0.44	89.44±1.18	10.50±0.33	40.68±0.53
		56-60	8.94±0.40	83.80±1.32	8.90±0.31	40.26±0.53
		64-68	9.44±0.37	78.82±1.68	7.57±0.31	38.74±0.54
		Mean	9.40±0.18	87.78±0.62	10.11±0.17	42.05±0.25
	HCD	24-28	9.94±0.41	92.55±1.08	11.58±0.36	46.84±0.69
		32-36	7.33±0.48	91.51±1.13	11.22±0.35	43.30±0.64
		40-44	9.72±0.37	89.22±1.52	10.31±0.42	41.37±0.55
		48-52	9.28±0.44	87.95±1.18	9.93±0.33	40.16±0.53
		56-60	9.78±0.40	82.50±1.32	8.61±0.31	39.22±0.53
		64-68	9.44±0.37	78.93±1.68	7.54±0.31	38.77±0.54
		Mean	9.25±0.18	87.11±0.62	9.86±0.17	41.61±0.25
	NW		9.32±0.13[c]	87.44±0.44[a]	9.98±0.12[a]	41.83±0.18[b]

[a-c]: Differences between means with different letters on the same column are significant ($p<0.05$). IB:Isa Brown, A-S: Atak-S, NW: Novogen White, NCD: Normal cage density, HCD: High cage density.

Table 5 – Effects of Hybrid, Cage Density and Age on Internal Egg Quality Parameters (*p* value).

GROUP		YOLK COLOR	HAUGH UNIT	ALBUMEN INDEX	YOLK INDEX
Hybrid		0.000	0.000	0.000	0.000
Density		0.216	0.682	0.982	0.672
Hybrid x Density		0.108	0.784	0.463	0.056
Age*	Linear	0.577	0.000	0.000	0.000
	Quadratic	0.078	0.000	0.025	0.000

*: Repeated-measures analysis of variance results based on time in the interval of 24-68 weeks.

Table 6 – Regression Coefficients and Probability Values on Factors Effective on Blood and Meat Spots in Multiple Logistic Regression Analysis.

FACTORS	*p*	COEFFICIENT (B)	SE	ODDS RATIO (EXP(B))
Hybrid	0.000			
Isa Brown		0.000	0.000	1.000
Atak-S		0.032	0.252	1.032
Novogen White		-3.937	1.019	0.020
Cage Density	0.007			
NCD		0.000	0.000	1.000
HCD		-0.687	0.255	0.503
Age (Weeks)	0.102			
24-28		0.000	0.000	1.000
32-36		0.815	0.499	2.259
40-44		0.407	0.526	1.503
48-52		0.815	0.499	2.259
54-60		1.215	0.482	3.372
64-68		1.142	0.484	3.132

The initial level of each factor is the reference level. SE: Standard error.
NCD: Normal cage density, HCD: High cage density.

may have affected the eggshell destruction strength. While eggshell destruction strength affects the crack and breaking rates in eggs, it may be stated that the shelf life of those with low strength is short (Kamanlı & Türkoğlu, 2018; Onbaşılar &Tabib, 2019). The shell thicknesses for IB, A-S and NW were determined respectively as 0.378, 0.347 and 0.370 mm ($p<0.001$). The determined values were within the ideal range of shell thickness values (Türkoglu & Sarıca, 2014). Considering that an eggshell is formed in about 18-20 hours in the uterus, it may be concluded that this effect is largely associated with the physiological structure of the animal (Onbaşılar &Tabib, 2019). The egg yolk color values for IB, A-S and NW were found respectively as 11.47, 10.93 and 9.32 ($p<0.001$). In this study, the yolk color values of the brown laying hens were found to be higher. Considering that the higher offering price of brown eggs in market conditions is formed by consumer demand, a darker color of egg yolks close to that of orange may be stated as an important factor that affects the brown egg preference by consumers. In the study, the Haugh unit values of the eggs of the IB, A-S and NW hybrids were found respectively as 85.02, 81.91 and 87.44 ($p<0.001$). In the findings obtained in this study, the eggs of all hybrids were found to be in the highest quality egg class based on the TSE standards for this parameter (Türkoglu & Sarıca, 2014). The albumen index values for IB, A-S and NW were determined respectively as 9.58, 8.67 and 9.98 ($p<0.001$). It is a desired situation for both hatching eggs and eggs consumed as food to have high albumen index values. In the findings of this study, the albumen index values were found to be in the normal range (Kamanlı & Türkoğlu, 2018). The yolk index values for the IB, A-S and NW hybrids were respectively 42.51, 41.49 and 41.83 ($p<0.001$). Light-colored yolk is responsible for chick formation in incubation, while dark-colored yolk is responsible for the nutrition of the chick. The yolk index is desired to be higher than 46 (Türkoglu & Sarıca, 2014). While the meat-blood spot observation ratios were close in the IB (18.52%) and A-S (18.98%) hybrids, this value was very low in the NW (0.46%) hybrid ($p<0.001$). Considering that a blood spot is formed by the disruption of the capillary veins in the follicle during the drop to the infundibulum and adherence of clots to the yolk, and meat spots are shaped by tissue parts separated from the oviduct during egg formation, this situation may be associated with the physiological structure of the animal. It is known that white laying lines show lower rates of meat-blood spots in eggs than brown laying lines. Some studies on egg quality (Kamanlı

& Türkoğlu, 2018; Ledvinka *et al*., 2012; Lordelo *et al*., 2020) stated that genotype is effective on both internal and external egg quality. In two different studies comparing three native laying hybrids and one foreign brown and one foreign white laying hybrids in terms of egg quality (Sarıca *et al*., 2010; Sarıca *et al*., 2012), genotype showed significant differences in all parameters. In a sense that supported the findings of this study, in their studies, it was determined that the Atak-S hybrid was similar to foreign hybrids in terms of egg weight values, while its shell thickness, Haugh unit and albumen index values were lower. Studies where the Haugh unit and albumen index values (Akkuş, 2016; Sarıca *et al*., 2010; Sarıca *et al*., 2012) were higher and meat and blood spot (Akkuş, 2016; Sarıca *et al*., 2010) and yolk color (Sarıca *et al*., 2010; Sarıca *et al*., 2012) values were lower in white laying hens were in agreement with this study.

In this study, cage density did not create a significant effect on any parameter except for the blood and meat spot ratio (p>0.05). Similarly, in the study by Geng *et al.* (2020) which used 4 different housing densities, the authors reported as a result of their analyses for the ages of 29 and 36 weeks that density did not create a difference on internal and external quality parameters. Sarica *et al*. (2008) reported in their study where 4 different cage density groups were formed (2000, 1000, 667 and 500 cm^2/hen) density did not show a significant difference in any parameter except for the shape index. The effect of density was found to be insignificant by Jahanian & Mirfendereski (2015) in all parameters and by Kang *et al*. (2016) in parameters other than eggshell destruction strength. In this study, the blood and meat spot observation ratios for the cage density groups were found as 16.05% for NCD and 9.26% for HCD (p<0.01). There was no significant difference in the NW hybrid based on the cage density groups, while the difference between NCD and HCD was caused by the brown eggs. In disagreement to the findings of this study, the study by Onbaşılar *et al*. (2009) which applied two different housing densities (646 and 323 cm^2/hen) reported the blood and meat spot ratios respectively as 18% and 21%. Similarly, in a study that applied 4 different housing densities (Sarica *et al*., 2008), there was no difference in this parameter in the eggs belonging to the IB hybrids.

In this study, it was determined that, in the eggs belonging to the hybrids, age had a significant effect on the egg weight, shape index, Haugh unit, albumen index and yolk index (p<0.01). The egg weight had a tendency to increase by time, and the egg weight of 55-56 g at the beginning reached 66-67 g towards the end of the study. This difference observed in time may be explained due to the physiological structure of the animal changing in time, the oviduct is developed, and the body size and live weight of the animal increase by time. In terms of the shape index, the width/length ratio of the eggs of the hybrids was higher at the beginning of the yield period, while there was a reduction towards the end. This change may be explained by the change in the activity of the muscles in the oviduct and pelvic bone anatomy by age. Additionally, the changed feeding programs in time based on the egg yield period and the changing nutritional value of the feed, as well as the changes in the climatic environmental conditions such as temperature inside the housing setup by seasons, may have affected the shape index. In this study, the highest Haugh unit value in the hybrid eggs was observed in the period of 24-28 weeks, which was the first period of the study, while the lowest value was observed in the period of 64-68 weeks at the end of the study. This change observed in time may be explained by the fact that albumen is heavier than the yolk, the egg weight increases by age, and the proportional value decreases. With aging, due to the physiological structure of the animal, the effect on the function of the egg albumen production in the oviduct may have reduced the albumen and yolk height by affecting the ligaments holding the egg albumen and yolk. The finding that the albumen index values in this study decreased by age supported this situation. The albumen index which was in the mean range of 11-12 at the beginning of the study was around the range of 6-7 at the end. The mean yolk index value in 24-28 weeks was in the range of 46-47, while there was a decrease in time, and the lowest mean values were observed in 64-68 weeks as 38-39. This may be interpreted as a reduction in the synthesis of egg yolk proteins in circulation with the effects of increasing stress towards the end of the trial (Kirunda & Scheideler, 2001) and that there was a reduction in the yolk index in connection to the lower egg yield and higher egg weight by aging due to the physiological structure of the animal. Onbaşılar *et al*. (2018) in their analyses at the ages of 20, 30, 40, 50, 60 and 70 weeks, reported similar results to this study that the egg weight increased throughout the yield period, while the shape index, Haugh unit and albumen and yolk indices decreased. Some other studies (Lacin *et al*., 2008; Yılmaz Dikmen *et al*., 2017; Akkuş, 2016; Ledvinka *et al*., 2012; Günlü *et al*., 2018; Petek & Yeşilbağ, 2017) reported that these parameters are affected by age, and those studies agreed with the results of this study. In this study, it was observed that age did not have a significant effect on the eggshell destruction strength, shell thickness, yolk color and meat-blood spot ratios. In a way to support the results of this study, some other studies did not find a significant effect of age on eggshell destruction strength (Ledvinka *et al*., 2012; Petricevic *et al*., 2017), shell thicknes (Akkuş, 2016; Petricevic *et al*., 2017) and meat-blood spots (Akkuş, 2016; Sokołowicz *et al*., 2018). Samiullah *et al*. (2017) reported in their study on hens at the ages of 44, 64 and 73 weeks that the change in the eggshell destruction strength, shell thickness and yolk color values were significant. Likewise, other studies (Lacin *et al*., 2008; Yılmaz Dikmen *et al*., 2017; Sokołowicz *et al*., 2018) also found these differences to be significant. This situation may have been caused by the feeding program within the yield period, length of the trial and the difference in the conditions of the trials.

Consequently, as the native hybrid had similar eggshell destruction strength values to the others despite its lower shell thickness, and it had a Haugh unit showing good quality based on the food codex despite lower values than the others, it was concluded that it could compete with the foreign hybrids in terms of egg quality. In terms of domestic breeding stock production on a limited level within laying hen breeding stocks serving as insurance, creation of foreign currency loss by the breeding stork material coming from abroad and avoidance of interruption of production in the sector by the possibility that imports of the material stop, it is important to use and promote native hybrids. In terms of egg quality, Atak-S may be preferred in breeding. Besides the economic significance of cage density in terms of housing more animals within a unit area, no significant difference was observed between NCD and HCD in any internal and external quality parameters except for meat and blood spot presence. It was observed that age was a significant factor affecting egg quality.

ACKNOWLEDGMENT

This research, as part of a PhD thesis, was supported by Ataturk University, Foundation of Scientific Researches Projects (Project number: PRJ2016/71).

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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