Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1374652

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 7 - Issue 1: 22-28 / January 2024

EFFECT OF GENOTYPE AND HOLDING DURATION ON SOME POST-HATCH TRAITS OF DAY-OLD BROILER PURE LINE CHICKS

Kadir ERENSOY[1]*, Musa SARICA[1], Numan KARAÇAY[1]

[1]Ondokuz Mayıs University, Agricultural Faculty, Department of Animal Science, 55139, Samsun, Türkiye

Abstract: In this study, it was aimed to investigate the effects of varying holding durations on some post-hatching characteristics of broiler pure line chicks with different selection backgrounds. Fifty d-old chicks from each of 3 dam (A1, A2, A3) and 1 sire (B1) ANADOLU-T broiler pure lines were used. Ten chicks of each genotype were treated with holding durations of 0, 12, 24, 36 and 48-h after hatching. At the end of each holding duration, individual chick weight (g), weight loss (g, %), chick length (mm), wing feather length (mm), rectal temperature (°C), yolk sac weight and percentage (g, %) and yolk-free body mass (g) were determined. Hatching egg weights were similar in A1 (60.9 g), A2 (60.9 g) and B1 (61.1 g) lines, but higher than A3 (59.2 g) (P<0.001). Chick weights were significantly different between genotypes both at hatch and at the each holding duration (P<0.01) and B1 line chicks were the heaviest, A3 the lightest. Absolute and relative mean weight loss occurred in the A3, B1, A1 and A2 lines as 3.7 g and 8.6%, 3.6 g and 8.8%, 3.0 g and 7.3% and 3.1 g and 7.2%, respectively (P<0.01). While the chick length increased linearly as the holding duration progressed in the B1 and A2 lines, it decreased after the 12-h holding period in the A1 line chicks (Interaction effect, P=0.026). The A1 (11.1 mm) and A3 (9.8 mm) line chicks had significantly shorter wing feather lengths (P<0.001) than A2 (15.4 mm) and B1 (15.1 mm) chicks. Rectal temperature values were lower in the A1 line than the others (P<0.01). Genotype x holding duration interaction on yolk sac weight and percentage was significant (P<0.05). A3 chicks with the highest yolk sac weight (6.2 g) and percentage (15.2%) at hatch had higher yellow sac absorption than other genotypes during the 48-h holding. Yolk-free body mass was the highest in B1 (36.7 g) and lowest in A3 chicks (34.5 g) (P<0.001). In conclusion, chick weight, chick length and yolk-free body mass were greatly influenced by egg weight. Regardless of the genotype, the extended holding durations at hatch resulted in deterioration in the general chick characteristics. Further studies are needed to reveal embryonic development and early post-hatch chick characteristics that are likely altered by different selection strategies for each pure line.

Keywords: Broiler, Pure line, Selection, Hatching, Holding duration, Chick quality

***Corresponding author:** Ondokuz Mayıs University, Agricultural Faculty, Department of Animal Science, 55139, Samsun, Türkiye
E mail: kadir.erensoy@omu.edu.tr (K. ERENSOY)
Kadir ERENSOY https://orcid.org/0000-0002-7479-6203
Musa SARICA https://orcid.org/0000-0001-5331-0596
Numan KARAÇAY https://orcid.org/0009-0003-9406-0361

Received: October 11, 2023
Accepted: November 23, 2023
Published: January 01, 2024

Cite as: Erensoy K, Sarıca M, Karaçay N. 2024. Effect of genotype and holding duration on some post-hatch traits of day-old broiler pure line chicks. BSJ Agri, 7(1): 22-28.

1. Introduction

In recent years, chicken meat production has reached the highest levels as a result of the increasing demand for animal protein sources. Worldwide chicken meat production has increased more than 10 times since 1961 (FAO, 2023). In addition to the higher number of chick production, the improvement in the meat production efficiency contributed significantly to the increase in meat production. While 85-90% of the productivity increase was attributed to genetic modification, the remaining 10-15% was contributed by hatchery practices management, feeding and other factors (Zuidhof et al., 2014).

The commercial expansion of the broiler industry after the 1950s has been associated with the development of large-scale hatcheries and large industrial incubators. However, as a result of this, the distance between hatcheries and farms has also increased (Bergoug et al., 2013). Current EU legislation (Council of the European Union, 2005) states that broiler chicks can be deprived of feed or water for a maximum of 24-h after hatching, which is based on the fact that the chick's metabolic reserves stored in the yolk sac can last up to 72-h (EFSA Animal Health and Welfare Panel (AHAW), 2011). Dehydration is an important problem in d-old chicks that are transported for a long time (Fairchild et al., 2006). Chick mortality is mostly seen in the first week of the rearing period and occurs due to poor adaptation to post-hatching management, handling and housing conditions (Bayliss and Hinton, 1990; Heier et al., 2002; Sarıca et al., 2022). In previous studies, it was stated that weight loss increased due to the increase in holding time, and this was caused by dehydration and yolk sac absorption (Tona et al., 2003; Peebles et al., 2004; Almeida et al., 2006; El Sabry et al., 2013; Erensoy et al., 2020). As the holding duration increases after hatching, chick length first increases and then decreases (Yalçın et al., 2013),

and chick length is positively correlated with body weight at slaughter (Molenaar et al., 2008).

When compared with their hybrids, broiler pure lines used as breeding material are more sensitive to environmental factors. Therefore, starting the rearing period by providing healthy chicks will be an important first step for the next production stages. In this study, it was aimed to investigate the effects of varying holding durations on some post-hatching characteristics of broiler pure line chicks with different selection backgrounds.

2. Materials and Methods

The study material, broiler pure line chicks, was obtained by incubation of eggs obtained from Eskişehir Transitional Zone Agricultural Research Institute at Ondokuz Mayis University Agricultural Faculty Research and Application Farm in January, 2019. In this study, 50 d-old chicks from each of 3 dam (A1: slow-feathering, A2: fast-feathering, A3: slow-feathering) and 1 sire (B1: fast feathering) of ANADOLU-T pure lines were used. The A1 and A3 lines are selected for reproduction, while A2 and B1 are for fast-growth, developmental and feed efficiency characteristics over generations.

Before incubation, 100 eggs from each genotype were individually weighed. Incubation of the eggs was carried out at 37.7 °C and 60% relative humidity during the first 18 d, and 37.4 °C and 70% between 18-21 d. The incubation period was terminated at the 510-h of incubation and 50 chicks from each pure line genotype were kept in the same tray in the hatching machine during the holding duration. Ten chicks of each genotype were treated with holding durations of 0, 12, 24, 36 and 48-h. All chicks were individually numbered at hatch and their initial weight (g) was recorded. At the end of each holding duration, individual chick weight (g), weight loss (g) and percentage (% of first hatch weight), chick length (mm, from beak to tip of middle finger), wing feather length (mm, from the 4th primary wing feather), rectal temperature (°C, 2 cm into the cloaca for 30 sec) (Noubandiguim et al., 2021), yolk sac weight (g) and percentage (%, relative to chick weight) and yolk-free body mass (g) were determined. At each holding duration, ten individually numbered chicks were killed by cervical dislocation and the residual yolk sac weight and yolk-free body mass (chick weight - yolk sac weight) were determined (Özlü et al., 2018 and 2020).

All statistical analyses were performed with SPSS version 21.0 (SPSS Inc., Chicago, IL, USA) using the GLM procedure. Differences between levels of main effects (genotype and holding duration) and their interactions were tested for significance (at $P<0.05$) using Tukey HSD's test for multiple comparisons.

3. Results

The effects of genotype and holding duration on some post-hatch traits of d-old broiler pure line chicks are given in Table 1. Hatching egg weights were similar in A1 (60.9 g), A2 (60.9 g) and B1 (61.1 g) lines, but higher than A3 (59.2 g) ($P<0.001$). Chick weights were significantly different between genotypes both at hatch and at each holding duration ($P<0.01$) and B1 line chicks were the heaviest, A3 the lightest. Chick weight at hatch (40.1 g) and 12-h holding duration (40.5 g) was higher than that at 24, 36 and 48-h ($P<0.01$). Absolute and relative weight loss occurred in the A3, B1, A1 and A2 lines as 3.7 g and 8.6%, 3.6 g and 8.8%, 3.0 g and 7.3% and 3.1 g and 7.2%, respectively ($P<0.01$). As the holding duration progressed, the weight loss also increased and the 12, 24, 36 and 48-h holding durations caused weight loss of 4.4%, 6.8%, 8.3% and 12.4%, respectively. While the chick length increased linearly as the holding duration progressed in the B1 and A2 lines, it decreased after the 12-h holding period in the A1 line chicks (Figure 1; Interaction effect, $P=0.026$). The A1 (11.1 mm) and A3 (9.8 mm) line chicks had significantly shorter wing feather lengths ($P<0.001$) than A2 (15.4 mm) and B1 (15.1 mm) chicks. It was determined that the wing feather length increased as the holding duration increased, and the length, which was 9.6 mm at the 0 h, reached 15.5 mm at 48-h holding time ($P<0.001$). Rectal temperature values were lower in the A1 line than the others ($P<0.01$). The rectal temperature, which was 37.1 °C after hatching, was highest at 12-h (38.3 °C) and 36-h (38.2 °C), and lowest at 48-h (36.2 °C) ($P<0.001$). Genotype × holding duration interaction on yolk sac weight (Figure 2) and percentage (Figure 3) was found significant ($P<0.05$). A3 chicks with the highest yolk sac weight (6.2 g) and percentage (15.2%) at hatch had higher yellow sac absorption than other genotypes during the 48-h holding period. Yolk-free body mass was the highest in B1 (36.7 g) and lowest in A3 chicks (34.5 g) ($P<0.001$). Yolk-free body mass, which was 35.1 g at the hatch, increased to 36.8 g at the end of the 12-h holding duration, and decreased with the advancing holding, reaching the lowest at 34.9 g at the 48-h ($P<0.01$).

4. Discussion

Broiler pure lines are breeding material with elite characteristics and more importance is attributed to them than their descendants (grand-parents, parents and hybrids) produced in other stages of production. Because the yield increases in their commercial hybrids are due to the genetic progress achieved at pure line level (Erensoy and Sarıca, 2022). Therefore, a good physiological start of the pure line chicks in the post-hatch period would have provided significant advantages for the later life.

The heaviest hatching weight of B1 chicks and the lightest of A3 chicks seem to be largely related to egg weight, in line with Iqbal et al. (2017) and Nowaczewski et al. (2022), because B1 eggs were the heaviest, while A3's were the lightest. In our study, heavier and taller chicks hatched from large eggs, consistent with Nangsuay et al. (2011).

Table 1. The effects of genotype and holding duration on some post-hatch traits of day-old pure line chicks

Genotype	Holding duration (h)	Chick weight (g) [1]	Chick weight (g) [2]	Weight loss (g)	Weight loss (%)	Chick length (cm)	Wing feather length (mm)	Rectal temperature (°C)	Yolk sac weight (g)	Yolk sac percentage (%)	Yolk-free body mass (g)
	0	39.1	39.1	-	-	19.0	9.1	37.1	4.5	11.4	34.6
	12	42.1	40.8	1.3	3.1	19.2	10.3	38.1	3.8	8.9	37.1
A1	24	40.7	38.1	2.6	6.4	18.8	11.2	37.0	3.5	9.2	34.6
	36	41.6	38.4	3.2	7.7	18.9	12.2	37.9	2.9	7.6	35.5
	48	41.9	36.8	5.1	12.1	19.0	12.5	35.4	2.5	6.7	34.3
	0	39.4	39.4	-	-	18.9	11.1	37.0	4.5	11.5	34.9
	12	43.2	41.6	1.7	3.8	19.0	11.8	38.6	3.4	8.1	38.1
A2	24	41.7	39.4	2.3	5.4	19.1	16.8	37.5	2.2	5.6	37.2
	36	42.1	38.6	3.5	8.3	19.2	18.6	38.0	2.1	5.4	36.5
	48	41.2	36.4	4.8	11.5	19.4	18.7	36.4	1.5	4.1	35.0
	0	40.3	40.3	-	-	18.4	7.3	36.6	6.2	15.2	34.1
	12	40.2	38.2	1.9	4.8	18.4	8.2	38.6	3.5	9.1	34.8
A3	24	41.8	38.4	3.4	7.9	18.8	9.3	38.4	3.1	7.9	35.3
	36	40.6	36.9	3.8	9.2	18.7	11.7	38.6	2.5	6.6	34.4
	48	41.1	35.6	5.4	13.2	19.0	12.6	36.3	1.7	4.8	34.0
	0	41.6	41.6	-	-	18.8	10.8	37.6	4.8	11.5	36.8
	12	43.9	41.3	2.5	5.8	18.9	13.2	38.1	4.3	10.3	37.1
B1	24	42.3	39.1	3.2	7.6	19.1	14.7	38.2	2.7	6.8	36.5
	36	42.4	38.9	3.5	8.1	19.5	18.5	38.5	2.1	5.5	36.8
	48	43.5	37.9	5.6	13.0	19.9	18.2	36.6	1.7	4.4	36.3
SEM		0.206	0.207	0.133	0.309	0.397	0.330	0.092	0.111	0.258	0.173
						Main effects					
Genotype		0.003	0.003	0.010	0.009	0.000	<0.001	0.002	0.007	<0.001	<0.001
A1		41.1^{b}	38.6^{bc}	3.0^{b}	7.3^{ab}	19.0^{b}	11.1^{b}	37.1^{b}	3.4^{a}	8.8^{a}	35.2^{bc}
A2		41.5^{b}	39.1^{ab}	3.1^{ab}	7.2^{b}	19.1^{ab}	15.4^{a}	37.5^{a}	2.8^{b}	7.0^{b}	36.3^{ab}
A3		40.8^{b}	37.9^{c}	3.6^{ab}	8.8^{a}	18.7^{c}	9.8^{b}	37.7^{a}	3.4^{a}	8.7^{a}	34.5^{c}
B1		42.8^{a}	39.8^{a}	3.7^{a}	8.6^{ab}	19.2^{a}	15.1^{a}	37.8^{a}	3.1^{ab}	7.7^{b}	36.7^{a}
Holding duration		0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
0 h		40.1^{b}	40.1^{a}	-	-	18.8^{c}	9.6^{c}	37.1^{c}	5.0^{a}	12.4^{a}	35.1^{b}
12 h		42.3^{a}	40.5^{a}	1.9^{c}	4.4^{d}	18.9^{bc}	10.9^{c}	38.3^{a}	3.7^{b}	9.1^{b}	36.8^{a}
24 h		41.6^{a}	38.8^{b}	2.9^{b}	6.8^{c}	18.9^{bc}	13.0^{b}	37.8^{b}	2.9^{c}	7.4^{c}	35.9^{ab}
36 h		41.7^{a}	38.2^{b}	3.5^{b}	8.3^{b}	19.1^{b}	15.3^{a}	38.2^{a}	2.4^{c}	6.3^{d}	35.8^{ab}
48 h		41.9^{a}	36.7^{c}	5.2^{a}	12.4^{a}	19.3^{a}	15.5^{a}	36.2^{d}	1.8^{d}	5.0^{e}	34.9^{b}
Interaction		0.633	0.450	0.867	0.850	0.026	0.210	0.140	0.018	0.007	0.436

1= chick weight at hatch (g), 2= chick weight at the end of the respective holding period (g), Means shown with different letters in the same column differ significantly from each other according to the Tukey HSD test. SEM: Standard error of the mean.

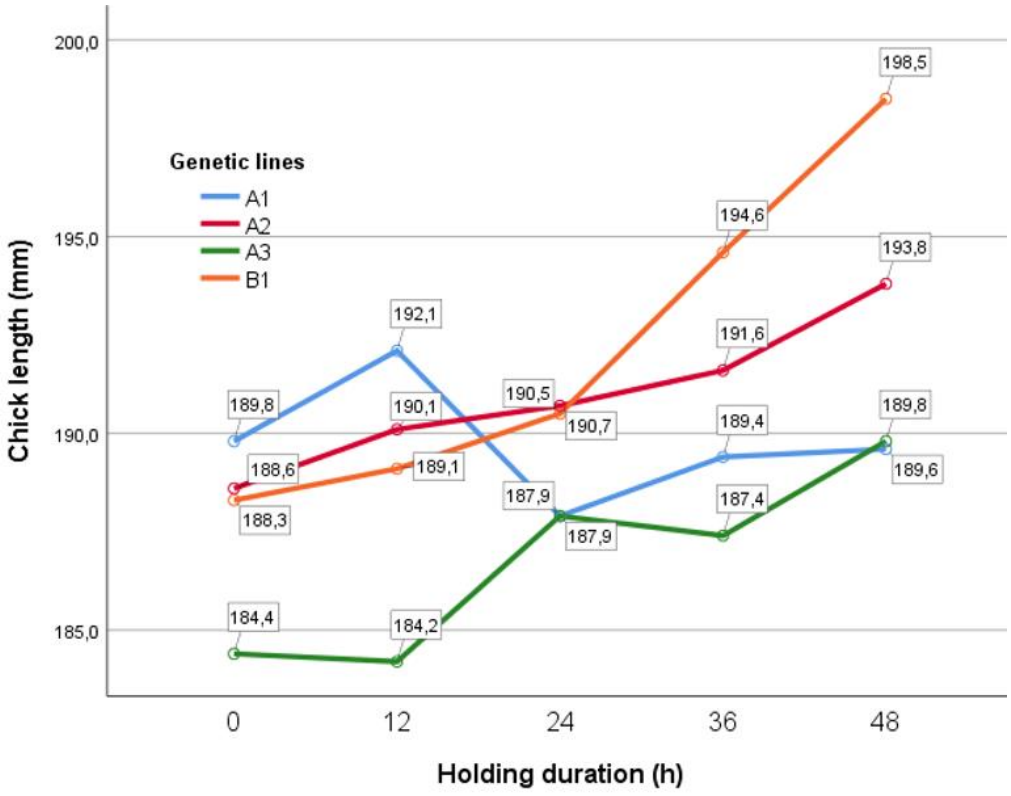

Figure 1. The effects of genotype and holding duration on chick length (mm).

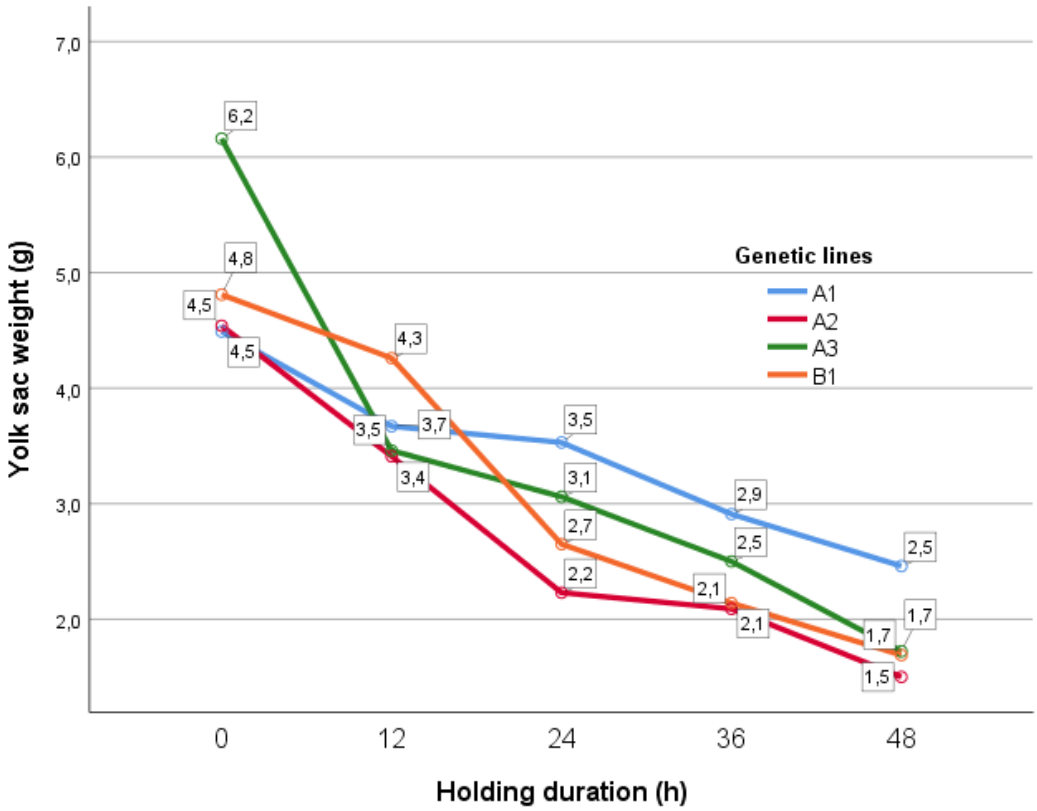

Figure 2. The effects of genotype and holding duration on yolk sac weight (g).

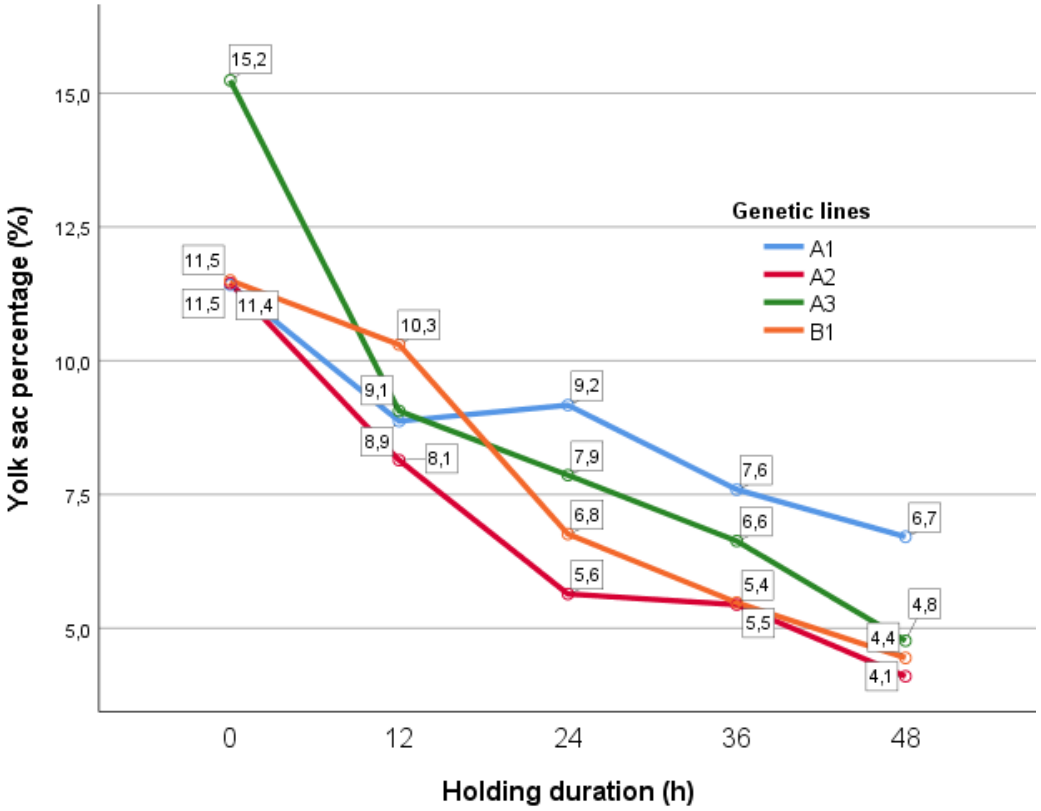

Figure 3. The effects of genotype and holding duration on yolk sac percentage (%).

This supports that chick weight and length, and yolk-free-body mass are largely determined by egg size. Although broiler chicks hatch in ~21-d on average, a 24-48-h period, called the hatching window, passes between the first and last hatched chicks (Tong et al., 2015). In addition to this, the long duration of hatchery procedures (sex separation, coding, weighing, vaccination, transportation, etc.) applied to pure line chicks after hatching causes the holding period to be longer (Erensoy et al., 2020). Although chicks can be deprived of feed and water for up to 72-h (Willemsen et al., 2010), lack of access to feed and water after hatching leads to weight loss due to dehydration and yolk sac absorption (Tona et al., 2003; Tong et al., 2015; Erensoy et al., 2020; Özlü et al., 2022). Similarly, the advancing holding duration increased weight loss in chicks in our study, regardless of genotype. Both relative and absolute weight loss were higher in A3 and B1 line chicks than in the others. However, this situation was surprising for A3 and this could probably be related to the earlier use of yolk sac reserves due to earlier hatch than others. Because the residual yolk sac, which was 6.2 g (15.2%) at the hatch, decreased to 1.7 g (4.8%) at the end of the 48-h holding period supports this hypothesis. Otherwise, less resources would be sufficient for the maintenance of the low yolk-free-body mass of A3 chicks (Nangsuay et al., 2011; Özlü et al., 2020). For the B1 line, more yolk absorption and thus weight loss could be expected in order to maintain the higher yolk-free body mass. In addition, prolonged holding times adversely affect post-hatch performance in terms of growth, immune system, stimulation of digestive enzymes and organ development (Gonzales et al., 2003; Willemsen et al., 2010). For this reason, prolonged holding durations after hatching is an important risk factor, especially for chicks that hatch earlier. In this case, we may assume that A3 chicks are subjected to longer holding durations, which makes it difficult to get a good start for post-hatch life.

Rectal temperature is a factor that affects post-hatch quality and early performance of chicks, and was between 39.4-40.5 °C in ROSS-308 hybrids (Aviagen, 2021; Özlü et al., 2022), and 37.1-37.8 °C in ANADOLU-T pure lines at d-old age (Noubandiguim et al., 2021). While our study results were similar to Noubandiguim et al. (2021), because we used the same pure line material, they were lower than ROSS-308 hybrids, which could probably be attributed to differences in metabolic heat production, possibly due to the genetics of pure line chicks. This is because selection for growth rate after hatching is likely to have altered embryonic metabolism and heat production by affecting the developmental pattern of the embryo (óDea et al., 2004; Janke, 2004). A recent study showed that ROSS-308 chicks were superior to ANADOLU-T pure lines in terms of growth characteristics (Erensoy and Sarıca, 2023). This may partly explain the elevated body temperature associated with the relatively higher metabolic rate of ROSS-308 hybrids. The lower rectal temperature of A1 line chicks than the others may also indicate lower energy requirements for post-hatch maintenance (Piestun et al., 2015). On the other hand, the higher absolute and percentage of residual yolk sac in A1 and A3 chicks

indicates that these genetic lines may require less energy for metabolic functions. Noubandiguim et al. (2021) reported that the A2 and B1 lines were fast-feathering, and this was also confirmed in our study. We speculate that these lines need more resources to support faster feather development in the early post-hatch (holding) period, which causes body reserves (yolk sac) to be depleted faster. In addition, the selection of A2 and B1 for higher body weight compared to A1 and A3 may have increased the metabolic rate (óDea et al., 2004), which may have contributed to the greater use of the yolk sac.

5. Conclusion

In conclusion, chick weight, chick length and yolk-free body mass are greatly affected by egg weight. Regardless of genotype, advancing holding duration causes deterioration in general chick traits. In addition, genetic lines responded to the same holding durations with varying levels of yolk sac absorption. Therefore, further studies are needed to reveal embryonic development and early post-hatch chick characteristics that are likely altered by different selection targets for each pure line. In this way, it seems possible to start the post-hatch period with better quality chicks by determining the optimum hatching management and procedures for each genetic line.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	K.E.	M.S.	N.K.
C	100		
D	100		
S	50	50	
DCP	100		
DAI	100		
L	100		
W	40	30	30
CR	40	40	20
SR	40	40	20
PM	10	90	
FA		100	

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

The authors confirm that experimental procedures were approved by the Local Animal Care and Ethics Committee of Ondokuz Mayıs University (protocol code: 2017/31, date: June 30, 2017).

Acknowledgments

The authors thank the technical and administrative staff working at the "Eskişehir Transitional Zone Agricultural Research Institute" where the study material was obtained, and the breeding selection practices of "ANADOLU-T" broiler pure lines were carried out.

References

Almeida JG, Vieira SL, Gallo BB, Conde ORA, Olmos AR. 2006. Period of incubation and posthatching holding time influence on broiler performance. Rev Bras Cienc Avic, 8: 153-158.

Aviagen. 2021. Factors affecting chick comfort and liveability from hatcher to brooding house. URL: https://www.thepoultrysite.com/articles/factors-affecting-chick-comfort-and-liveability-from-hatcher-to-brooding-house (accessed date: September 1, 2023).

Bayliss PA, Hinton MH. 1990. Transportation of broilers with special reference to mortality rates. Appl Anim Behav Sci, 28(1-2): 93-118.

Bergoug H, Burel C, Guinebretiere M, Tong Q, Roulston N, Romanini CEB, Exadaktylos V, Mcgonnell IM, Demmers TGM, Verhelst R, Bahr C, Berckmans D, Eterradossi N. 2013. Effect of pre-incubation and incubation conditions on hatchability, hatch time and hatch window, and effect of post-hatch handling on chick quality at placement. Worlds Poult Sci J, 69(2): 313-334.

Council of the European Union. 2005. Council Regulation (EC) No 1/2005 of 22 December, 2004, on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97. Off. J. Eur. Union L 3: 1–44.

EFSA Panel on Animal Health and Welfare (AHAW). 2011. Scientific opinion concerning the welfare of animals during transport. EFSA J, 9: 125.

El Sabry MI, Yalçın S, İzzetoğlu GT. 2013. Interaction between breeder age and hatching time affects intestine development and broiler performance. Livest Sci, 157(2-3): 612-617.

Erensoy K, Noubandiguim M, Sarıca M, Yamak US. 2020. Relationship between transportation conditions and live weight after incubation in broiler pure lines of different feathering rates. Turkish JAF Sci Tech, 8(6): 1256-1260.

Erensoy K, Sarıca M. 2022. Fast growing broiler production from genetically different pure lines in Turkey. 1. Parental traits: growth, feed intake, reproduction, and hatching traits. Trop Anim Health Prod, 54(5), 322.

Erensoy K, Sarıca M. 2023. Fast growing broiler production from genetically different pure lines in Turkey. 2. Broiler traits: growth, feed intake, feed efficiency, livability, body defects and some heterotic effects. Trop Anim Health Prod, 55(1): 61.

Fairchild BD, Northcutt JK, Mauldin JM, Buhr RJ, Richardson LJ, Cox NA. 2006. Influence of water provision to chicks before placement and effects on performance and incidence of unabsorbed yolk sacs. J Appl Poult Res, 15(4): 538-543.

Food and Agriculture Organization of the United Nations (FAO). 2023. FAOSTAT statistical database. Rome, FAO. URL: https://www.fao.org/faostat/en/#data/QCL (accessed date: September 1, 2023).

Gonzales E, Kondo N, Saldanha ES, Loddy MM, Careghi C, Decuypere E. 2003. Performance and physiological parameters of broiler chickens subjected to fasting on the neonatal period. Poult Sci, 82(8): 1250-1256.

Heier BT, Høgåsen HR, Jarp J. 2002. Factors associated with mortality in Norwegian broiler flocks. Prev Vet Med, 53(1-2):

147-158.

Iqbal J, Mukhtar N, Rehman ZU, Khan SH, Ahmad T, Anjum MS, Pasha RH, Umar S. 2017. Effects of egg weight on the egg quality, chick quality, and broiler performance at the later stages of production (week 60) in broiler breeders. J Appl Poult Res, 26(2): 183-191.

Janke O. 2004. Comparative investigations of heat production and body temperature in embryos of modern chicken breeds. Avian Poult Biol Rev, 15: 191-196.

Molenaar R, Reijrink IAM, Meijerhof R, Van den Brand H. 2008. Relationship between hatchling length and weight on later productive performance in broilers. Worlds Poult Sci J, 64(4): 599-604.

Nangsuay A, Ruangpanit Y, Meijerhof R, Attamangkune S. 2011. Yolk absorption and embryo development of small and large eggs originating from young and old breeder hens. Poult Sci, 90(11): 2648-2655.

Noubandiguim M, Erensoy K, Sarica M. 2021. Feather growth, bodyweight and body temperature in broiler lines with different feathering rates. S Afr J Anim Sci, 51(1): 88-97.

Nowaczewski S, Babuszkiewicz M, Szablewski T, Stuper-Szablewska K, Cegielska-Radziejewska R, Kaczmarek S, Sechman A, Lis MW, Kwaśniewska M, Racewicz P, Jarosz Ł, Ciszewski A, Nowak T, Hejdysz M. 2022. Effect of weight and storage time of broiler breeders' eggs on morphology and biochemical features of eggs, embryogenesis, hatchability, and chick quality. Animal, 16(7): 100564.

óDea EE, Fasenko GM, Feddes JJR, Robinson FE, Segura JC, Ouellette CA, van Middelkoop JH. 2004. Investigating the eggshell conductance and embryonic metabolism of modern and unselected domestic avian genetic strains at two flock ages. Poult Sci, 83(12): 2059-2070.

Özlü S, Erkuş T, Kamanlı S, Nicholson AD, Elibol O. 2022. Influence of the preplacement holding time and feeding hydration supplementation before placement on yolk sac utilization, the crop filling rate, feeding behavior and first-week broiler performance. Poult Sci, 101(10), 102056.

Özlü S, Shiranjang R, Elibol O, Brake J. 2018. Effect of hatching time on yolk sac percentage and broiler live performance. Rev Bras Cienc Avic, 20: 231-236.

Özlü S, Uçar A, Romanini CEB, Banwell R, Elibol O. 2020. Effect of posthatch feed and water access time on residual yolk and broiler live performance. Poult Sci, 99(12): 6737-6744.

Peebles ED, Keirs RW, Bennett LW, Cummings TS, Whitmarsh SK, Gerard PD. 2004. Relationships among post-hatch physiological parameters in broiler chicks hatched from young breeder hens and subjected to delayed brooding placement. Int J Poult Sci, 3(9): 578-585.

Piestun Y, Zimmerman I, Yahav S. 2015. Thermal manipulations of turkey embryos: The effect on thermoregulation and development during embryogenesis. Poult Sci, 94(2): 273-280.

Sarıca M, Karakoç K, Erensoy K. 2022. Effects of varying group sizes on performance, body defects, and productivity in broiler chickens. Arch Anim Breed, 65(2): 171-181.

Tona K, Bamelis F, De Ketelaere B, Bruggeman V, Moraes VM, Buyse J, Onagbesan O, Decuypere E. 2003. Effects of egg storage time on spread of hatch, chick quality, and chick juvenile growth. Poult Sci, 82(5): 736-741.

Tong Q, Demmers T, Romanini CEB, Bergoug H, Roulston N, Exadaktylos V, Bahr C, Berckmans D, Guinebretière M, Eterradossi N, Garain P, McGonnell IM. 2015. Physiological status of broiler chicks at pulling time and the relationship to duration of holding period. Animal, 9(7): 1181-1187.

Willemsen H, Debonne M, Swennen Q, Everaert N, Careghi C, Han H, Bruggeman V, Tona K, Decuypere E. 2010. Delay in feed access and spread of hatch: importance of early nutrition. Worlds Poult Sci J, 66(2): 177-188.

Yalçın S, İzzetoğlu GT, Aktaş A. 2013. Effects of breeder age and egg weight on morphological changes in the small intestine of chicks during the hatch window. Br Poult Sci, 54(6): 810-817.

Zuidhof MJ, Schneider BL, Carney VL, Korver DR, Robinson FE. 2014. Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005. Poult Sci, 93(12): 2970-2982.