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The effects of body weight and age on performance, egg quality, blood parameters, and economic production of laying hens

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ABSTRACT: This study was conducted to investigate the effects of body weight (BW) on performance, egg quality, blood parameters, and economic production of Lohmann white laying hens. At the beginning of the experiment, hens were weighed and groups were classified into the experimental groups, as follow: light (<1500 g), medium (1500-1750 g), and heavy (>1750g) as to the standard deviation of the mean. A total of 288 Lohmann white laying hens, 44 wks of age, were allocated randomly to three groups, each formed 24 replicate cages as subgroups, comprising of four hens. The study was conducted over a period of 36 wks. Feed and water were offered ad libitum in the experiment. Performance parameters were significantly affected by body weight except for cracked egg. Considering the egg production, differences among the groups were significant (P<0.001). Egg production in the light group was higher than that of the medium and the heavy group. However, egg weight was determined to be lower in the light group (66.58 g) than in medium (67.54 g) and heavy hens (68.84 g). Hens in light body weight had lower feed intake and feed conversion ratio (FCR) than hens in heavy body weight. There were no alterations in egg quality parameters in response to increased body weight except for shell strength (SS) and yolk color. SS decreased linearly (P<0.001) and yolk color (YC) increased with BW. Other egg quality parameters did not change as BW increased. There was no change in the metabolic profile in response to increased BW except for glucose. Heavy hens had greater serum glucose concentrations than light and medium hens. This study emphasized that body weight affected the laying performance, and some egg quality parameters, but had no significant effect on metabolic profile except for glucose. As a result, it was found that there was a positive relationship between the egg weight and the body weight of the hens. In this case, it is possible to produce more eggs with less feed by increasing the number of light and medium-weight chickens in the flock for profitable livestock.

Keywords: Laying hen; body weight; performance; egg quality; blood parameters; economic production

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INTRODUCTION

The two most important criteria of economic farming in poultry are egg production and feed efficiency. However, egg production and some characteristics of eggs are absolute effective factors in ensuring the continuity of breeding in poultry (Nazligul et al., 2001; Lacin et al., 2008; Kumar et al., 2018; Muir et al., 2022a). Efforts to increase egg production in poultry are to increase the average egg production per hen in number and improve its quality. It is known that egg production is brought to a certain level in commercial egg flocks used for egg production, but the desired egg weight is not always reached, and this is under the effect of various factors. One of the main factors affecting egg size and feed consumption is body weight. Selection practices to increase the live weight have brought about a decrease in egg production and an increase in egg weight in poultry. There are two reasons why overweight hens lay heavier but fewer eggs; they ovulate larger egg yolks, and accordingly, their ovaries lose their function very quickly (Lacin et al., 2008; Najib and Al-Yousif 2014; Hussain et al., 2016; Muir et al., 2022b).

The uniformity of body weights in laying hens is an important management problem. Uniformity at the beginning of the flock and during the laying period is one of the most important factors that increase egg production. Having the right body weight and uniformity during the growth period is essential for early maturation and egg production in poultry houses. Therefore, the control of body weight in laying hens is very important. (Oke et al., 2004; Muir et al., 2022a,b). The objective of the present study is to evaluate the effect of different body weight on performance, egg quality, metabolic profile, and economics of production.

MATERIALS AND METHODS

Animal, treatments, and management

All procedures in the current study were approved by the Animal Ethics Committee of Atatürk University (25/12/2008-4673-5). At the beginning of the experiment, a total of 288 Lohmann White layers, 44 wks of age, were weighed, and were assigned to 3 experimental groups according to body weight (light (<1500 g), medium (1500-1750 g), and heavy (>1750g)) as to the standard deviation of the mean. Each experimental group consisted of 24 replicated cages (48x45x45 cm, in width x depth x height respectively) of four hens each.

Samples and data collection

The study was conducted over a period of 36 wks. Feed and water were available ad libitum in the experiment. The commercial layer diet was formulated to meet NRC nutrient requirements. The ingredients and chemical composition of the basal diet are shown in Table 1. Hens were also subjected to a 17L:7D cycle. Feed consumption and egg production were recorded daily; egg weight was measured at 2-weeks intervals and body weight was measured monthly. Feed conversion ratio (FCR) was expressed as a kilogram of feed consumed per kilogram of egg produced. To assess egg quality parameters, 24 eggs were randomly

Table 1. Ingredients and composition of the basal feed

Ingredients	(%)	Chemical analysis (analysed on dry matter basis)	
Corn	52.81	Dry matter (%)	89.47
Soybean meal	18.13	Crude Protein (%)	16.50
Barley	7.53	Ether extract (%)	4.88
Sunflower meal	7.50	Crude fibre (%)	4.49
Limestone	9.00	Crude ash (%)	11.70
Soybean oil	3.00	ME, (kcal/kg-1)[2]	2720
Dicalcium phosphate	1.15		
Vitamin and mineral premix[1]	0.2		
Salt	0.50		
Methionine (DL-methionine)	0.13		
Lysine (L-lysine hydrochloride)	0.05		

[1] Per kilogram contained: vitamin A 12.000.000 IU; vitamin D3 2.500.000 IU; vitamin E, 30.000 mg; vitamin K 34.000 mg; vitamin B1, 3.000 mg; vitamin B2, 6.000 mg; nicotin amid, 30.000 mg; Ca-D-pantothenate, 10.000 mg; vitamin B6, 5.000 mg; vitamin B12, 15 µg; folic acit, 1.000 mg; D-Biotin, 50 mg; Cholin, 300.000 mg; vitamin C, 50.000 mg; Mn, 80.000 mg; Fe, 60.000 mg; Zn, 60.000 mg; Cu, 5.000 mg; I, 2.000 mg; Co, 500 mg; Se, 150 mg;
[2]ME: Metabolizable energy calculated according to AOAC (2005).

collected from each group every month. Egg quality parameters were shape index (SI), shell strength (SS), shell thickness (ST), albumen index (AI), yolk index (YI), yolk color (YC), and Haugh unit (HU). They were calculated using the following formulas as summarized by Monira et al, (2003). Shape index (%) = (egg width, cm/egg length, cm)×100; shell strength (kg/cm^2) was determined by using a machine with the spiral pressure system, shell thickness ($mm\times10^2$) was determined in 3 different parts by using micrometer; albumen index (%) = (albumen height, mm/average of albumen length, mm and albumen width, mm)×100; yolk index (%) = (yolk height, mm/yolk diameter, mm)×100; yolk color was determined by using commercially available yolk colour fan according to the CIE standard colorimetric system (Yolk Color Fan, the CIE standard colorimetric system, F. Hoffman-La Roche Ltd., Basel, Switzerland), and Haugh unit = 100×log (AH+ 7.57-1.7×EW037), where AH = albumen height, mm and EW = egg weight, g.

At the end of the experiment, 6 animals from each group were selected and 3 ml of blood samples were drawn from wing vein into additive-free vacutainers to determine metabolic profile. Blood samples were centrifuged at 3,000 x g for 5 min at 20°C for separation of serum. Aliquots were kept at -20°C until laboratory analyses for alkaline phosphatase (Alp), total protein (TP), albumin (Alb), glucose (Glu), triglyceride (TG), cholesterol (Cho), very low-density lipoprotein (VLDL), calcium (Ca), phosphorous (P) and creatine (Cre) concentrations using commercial kits (DDS®, Diasis Diagnostic Systems Co., Istanbul 80270, Turkey).

The value of agricultural outputs obtained from a production branch as a result of economic activities in a production period is expressed as Gross Production Value (GPV). The income from eggs in laying hens is GPV. Since labor, heating, electricity, periodic maintenance and repair, etc. expenses in laying hens are considered as fixed costs, only feed expense is taken as variable expense (VC). Gross Margin (GPV-VC) is calculated by subtracting variable costs from GPV (Yıldız and Dagdemir, 2017; Askan et al., 2018). Economic analysis was calculated in U.S. dollars.

Statistical Analysis

The data were analyzed according to Completely Randomized Design under the factorial arrangement using general linear model (GLM) procedures (IBM SPSS version 20.0). The correlation between body weight and performance characteristics were tested. The comparison of means was made using Duncan's Multiple Range Test. Statistical significance is set at P<0.05. The following mathematical model was applied:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha \times \beta)_{ij} + e_{ijk} ,$$

where:

$Y_{ijk=}$ observation of dependent variable recorded on ith and jth treatment groups,

μ = population mean

α_i = effect of jth body weight groups (j = 1, 2, 3; light (<1500 gr), medium (1500-1750 gr), and heavy (>1750gr))

β_j = age period group

e_{ijk} = experimental error

RESULT AND DISCUSSION

Laying performance

The changes in BW during the experiment are presented in Figure 1 and Table 2. It is seen that all treatment groups maintained their body weight differences throughout the experiment. The differences among the treatment groups at the initial BW, mid-BW and at the final BW are determined to be significant (P<0.0001) (Table 2).

Tablo 3 shows laying performance parameters of hens in the various body weight groups. Average body weight values were 1,572.45, 1,710.47, and 1,846.50 g for light, medium, and heavy groups respectively.

Daily feed consumption of laying hens varies depending on factors such as breed, age, body weight, laying period, the energy level of the ration, environmental temperature, and health status. Daily feed consumption for light, medium, and heavy groups were found 115.19, 116.58 and 118.09 g, respectively. The differences between the groups in terms of feed consumption were found to be statistically significant (P<0.009). Although the effect of age on feed consumption was significant (P<0.001), the effect of group x age interaction was not statistically significant. There was a positive significant correlation between body weight and feed consumption (r= 0.994, P<0.001). The heavy hens consumed more feed than light hens. Feed consumption increased linearly as the body weight increased. Similar to the findings ob-

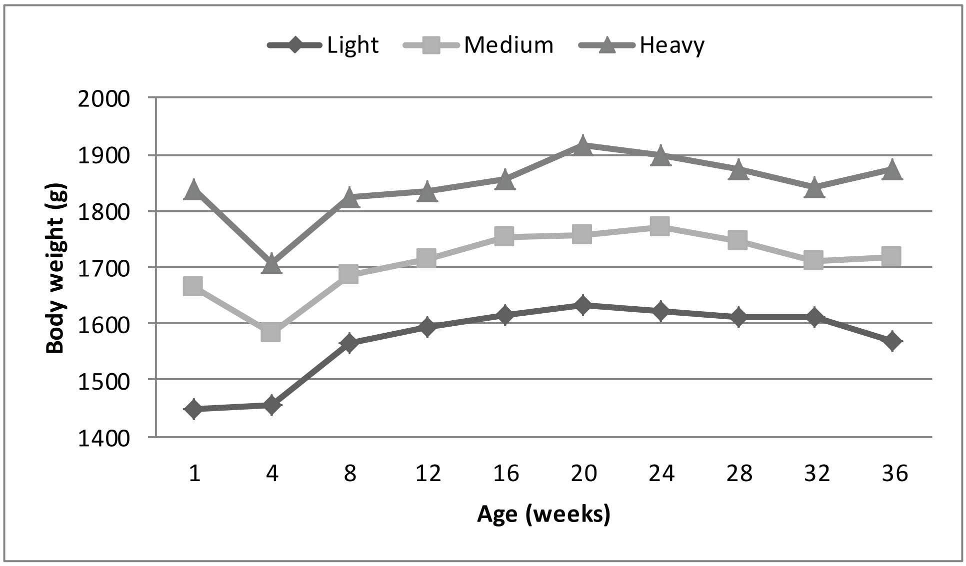

Figure 1. Body weight changes of light, medium and heavy groups during the experiment

Table 2. The body weight changes of light, medium and heavy groups during the experiment

	Body weight (BW)				
	Light	Medium	Heavy	SEM	P-value
Initial BW (kg)	1447.73^{c}	1663.91^{b}	1836.91^{a}	11.16	0.0001
Mid-BW (kg)	1633.02^{c}	1757.94^{b}	1916.27^{a}	20.23	0.0001
Final BW (kg)	1569.87^{c}	1717.33^{b}	1872.55^{a}	27.11	0.0001

^{a,b,c}: Means with different superscript in the same column are significantly different (p<0.05).
BW: Body weight

Table 3. The effects of body weight on the laying performance

	Body weight (BW)				P-value		
	Light	Medium	Heavy	SEM	BW	Age (A)	BWxA
BW (kg)	1572.45^{c}	1710.47^{b}	1846.50^{a}	6.72	0.0001	0.0001	0.193
FC (g)	115.19^{b}	116.58^{ab}	118.09^{a}	0.67	0.009	0.001	0.906
EP (%)	82.81^{a}	79.78^{b}	76.65^{c}	0.54	0.001	0.001	0.836
FCR	2.17^{c}	2.26^{b}	2.34^{a}	0.02	0.0001	0.0001	0.097
EW (g)	66.58^{c}	67.54^{b}	68.84^{a}	0.19	0.0001	0.0001	0.736
CE (%)	0.95	0.96	1.15	0.10	0.317	0.0001	0.828

^{a,b,c}: Means with different superscript in the same column are significantly different (p<0.05).
BW= body weight; FC= Daily feed consumption (g/d); EP= egg production FCR= feed conversion ratio (kg feed consumed per kg egg produced); EW=egg weight; CE=cracked egg (%)

tained in our study, Balcıoglu et al., (2005); Kumar et al., (2018); Akter et al., (2019), Anene et al., (2021) and Muir et al., (2022b) reported that hens with lower body weight consumed less feed compared to hens with higher body weights. The higher feed consumption obtained in heavy groups compared to the light groups can be explained by the highest survival requirements and abdominal fat ratios. In addition, since egg weight is one of the factors affecting feed consumption, the light group may have lower feed consumption than that of the heavy group.

The average egg production of the light, medium and heavy groups was found as 82.81, 79.78, and 76.65 % respectively. While the highest egg production was obtained from the light group and the lowest was obtained from the heavy group. The differences between the body weight groups and the effect of age on egg production were significant (P<0.01). Negative and significant correlations were found between egg production and body weight (r=-0.985, P<001), and between egg production and feed consumption (r=-0.992, P<0.05). In contrast to the obtained results of this study, Kirikci et al., (2004), Lacin et al., (2008) and Muir et al., (2022b) reported that body weight had no effect on egg production. Seker et al., (2005), Balcıoglu et al., (2005), Akbas and Takma, (2005), and Saleem et al., (2022) stated that the effect of body weight on egg production was significant.

The mean FCR values of light, medium, and heavy treatment groups were determined as 2.17, 2.26, and 2.34, respectively. The differences between body weight groups were found to be statistically significant (P<0.0001). The FCR of heavy and medium groups was higher than the light group (P<0.0001). In other words, as the body weight increase, the hens produced fewer eggs despite consuming more feed. Similar to our study, Lacin et al., (2008) and Muir et al., (2022b) reported that the FCR increased when the body weight increased.

Egg weight varies depending on the hereditary structure, environmental temperature, age, body weight, and season. The mean values of egg weight were 66.58, 67.97, and 68.84 g for light, medium, and heavy groups respectively. The effect of body weight on egg weight was found to be significant (P<0.0001). A positive correlation was found between body weight and egg weight. Lower egg weight was obtained from the light group compared to the medium and heavy groups. The highest egg weight was found in the heavy group. In addition, it was determined that egg weight increased significantly (P<0.01) depending on age (p<0.0001). Although hens in the heavy group produced heavier eggs than hens in medium and light groups, egg production decreased (P<0.001) compared to other body weight groups. The effect of body weight x age interaction on egg weight was insignificant. In agreement with the present study, Nazlıgul et al., (2001), Ipek et al., (2003), Kirikci et al., (2004), Seker et al., (2005), Lacin et al., (2008), Jatoi et al., (2015), Guo et al., (2021), and Muir et al., (2022a,b) reported that an increase in body weight positively increased egg weight. Leeson et al., (1997) and Muir et al., (2022b) reported that smaller birds consistently ate less feed throughout laying, and this resulted in a loss of egg weight.

The average cracked egg ratios of light, medium and heavy groups were determined as 0.95, 0.96, and 1.15%, respectively. Although there were no significant differences between the treatment groups in terms of cracked eggs, the heavy group had a higher cracked egg ratio than hens in the other groups. In addition, despite the effect of age on the cracked egg rate being significant (P<0.0001), the effect of body weight x age interaction was not found to be statistically no significant.

Egg quality

The effects of body weight on egg quality parameters are shown in Table 4. Most of the egg quality parameters are affected by various factors such as genetic structure, feeding, health, age, housing, storage period, and conditions (Bain et al., 2016). Egg quality is composed of those characteristics that affect the egg's acceptability to the consumer (Stadelman, 1977). Except for SS and YC, there was no significant effect of body weight on the egg qualities. All the egg quality parameters were affected by age except for SI and ST. The effect of body weight group by age interaction on all egg quality parameters was insignificant. The SI is an important quality factor. Because the normal index of eggs is of great importance in marketing. While there was a significant difference in SI by age, the effect of the body weight group on shape index was not significant. In this study, it was determined

Table 4. The effect of different body weight groups on egg quality of hens

	Body weight (BW)				P-value		
	Light	Medium	Heavy	SEM	BW	Age (A)	BWxA
SI	74.53	73.49	73.72	0.60	0.433	0.676	0.323
SS	1.32[a]	1.14[b]	1.12[b]	0.04	0.001	0.0001	0.081
ST	0.38	0.38	0.37	0.05	0.765	0.268	0.547
SW	8.54	8.38	8.65	0.09	0.098	0.002	0.434
YC	7.81[b]	8.08[a]	7.90[b]	0.82	0.048	0.001	0.194
YI	41.60	41.54	42.06	0.38	0.573	0.001	0.146
AI	7.92	8.08	7.50	0.19	0.076	0.01	0.058
HU	79.58	80.47	78.12	0.75	0.09	0.01	0.38

[a,b,c]: Means with different superscript in the same column are significantly different (p<0.05).
EW=egg weight; SI= shape index; SS=shell strength (kg/cm^2); ST= shell thickness (mm); SW=Shell weight (g); YC= yolk color; YI= yolk index (%); AI= albumen index (%); HU= Haugh unit

that the SI values ranged from 73.72 to 74.53. It has been observed that the said values are within the desired and required limits. These results are in agreement with the findings of Altan et al., (1998), and Muir et al., (2022b). However, Turkmut et al., (1999) and Kirikci et al., (2004) noted that shape index was affected by body weight.

The shell strength of light, medium, and heavy groups were 1.32, 1.14, and 1.12 kg/cm^2 respectively. There was a significant difference in SS among the BW groups (P<0.0001). As body weight increased, SS decreased linearly (P<0.001). There were no significant effects of body weight and body weight by age interaction on ST. The yolk index changed with flock age (P < 0.001). However, there were no significant effects of body weight and the interaction body weight and age on the YI. Yolk colours were 7.92, 8.08, and 7.50 for light, medium and heavy groups, respectively. YC was affected by different body weight groups. While the effect of age on YC was significant (P < 0.001), whereas the effect of the interaction of body weight and age was not significant. The highest YC was obtained in the medium body weight group compared to both light and heavy groups. Similar to the present finding, Altan et al., (1998) and Lacin et al., (2008) found significant differences between the body weight groups for yolk color.

The haugh unit is a function of the AI, and both of them are highly correlated). In this study, both AI and HU were not affected by body weight and the interaction of BW and age The effect of age on haugh unit and AI was significant (P<0.01). In contrast to, Altan et al., (1998) and Kirikci et al., (2004) reported that haugh unit was affected by body weight. Nazlıgul et al., (2001) and Seker et al., (2005) determined that were significantly affected by season of the year and haugh unit, AI and YI decreased with the age.

Metabolic profile

The effect of different body weight groups on the metabolic profile is presented in Table 5. In this study, except for glucose, other metabolic parameters were not affected by body weight. The heavy hens had higher serum glucose concentration than light and medium hens. Increasing body weight linearly increased serum glucose (P<0.01). Although the difference is not significant, Alp, TP, TG, Cho, VLDL, P, and Cre levels were found to be relatively higher in the heavy group compared to light and medium body weight groups.

Economic analysis

When light, medium, and heavy body weight groups are economically compared, the group with the highest gross production value and the lowest variable cost is the light group (Table 6). The amount of feed consumed per egg in the heavy group is high and the gross profit margin per egg is at the lowest level.

Table 5. The effects of different body weight on metabolic profile

	Body weight (BW)				
	Light	Medium	Heavy	SEM	P-value
Alp	1037.3	1005.8	1095.3	114.0	0.85
TP	5.86	6.00	6.36	0.18	0.14
Alb	1.78	1.85	1.76	0.04	0.30
Glu	373.0^b	359.2^b	434.0^a	17.9	0.01
TG	1338.0	1227.8	1360.9	110.8	0.67
Cho	261.75	250.00	284.92	13.14	0.18
VLDL	174.75	165.15	182.59	14.09	0.68
Ca	14.57	14.50	14.48	0.15	0.92
P	4.80	4.60	5.02	0.38	0.74
Cre	2.19	2.01	2.38	0.24	0.55

^{a,b,c}: Means with different superscript in the same column are significantly different (p<0.05).
Alp= Alkaline phosphatase (mg/dL), TP= Total protein (mg/dL), Alb= Albumin (mg/dL), Glu= Glucose (mg/dL), TG= Triglyceride (mg/dL), Chol= Cholesterol (mg/dL), VLDL= Very low-density lipoprotein (mg/dL), Ca= kalsiyum (mg/dL), P= phosphorus (mg/dL), Cre= creatine.

Table 6. Economic analysis of egg production

	Light	Medium	Heavy
Total Number of Chickens	288	288	288
Average Number of Eggs Per Day	238.5	229.8	220.8
Total Daily Consumed Feed (Kg)	33.174	33.575	34.010
Egg Price ($/piece)	0.119	0.119	0.119
Feed Price ($/Kg)	0.298	0.298	0.298
Daily Gross Production Value ($)	28.382	27.346	26.275
Daily Variable Cost ($)	9.886	10.005	10.135
Daily Gross Margin ($)	18.496	17.341	16.140
Daily Feed Conversion Rate	287.092	273.316	259.253
Average Number of Eggs Per Chicken	0.828	0.798	0.767
Amount of Feed Consumed Per Egg (Kg)	0.139	0.146	0.154
Gross Production Value Per Egg ($)	0.099	0.095	0.091
Variable Cost Per Egg ($)	0.041	0.044	0.046
Gross Margin Per Egg ($)	0.057	0.051	0.045
Feed Conversion Rate Per Egg	237.910	218.241	198.800

CONCLUSION

As a result, it was determined that there was a positive relationship between the the body weight and egg weight of the hens. The heavier eggs were obtained from heavier chickens. The relationship between egg production and egg weight was negative and egg weight decreased as the egg production increased. Considering the egg yield and FCR values, it is observed that the heavy group consumes more feed and produces less eggs. In this case, it may be possible to produce more eggs with less feed by increasing the number of light and medium-weight chickens in the flock for profitable livestock.

ETHICS APPROVAL

All procedures were approved by the Local Ethics Committee (25/12/2008-4673-5) of the Ataturk University.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Akbas Y, Takma C (2005). Canonical correlation analysis for studying the relationship between egg production traits and body weight, egg weight and age at sexual maturity in layers. Czech Journal of Animal Science 50: 163–168.

Akter Y, Groves PJ, Liu SY, Moss AF, Anene D, O'Shea CJ (2019) Association of feed to egg efficiency with body weight and digestive organ characteristics in laying hens. Proceedings of the Australian Poultry Science Symposium 30, pp. 249-252

Altan O, Oguz I, Akbas Y (1998) Effects of selection for high body weight and age of hen on egg characteristics in japanese quail. Turkish Journal of Veterinary and Animal Sciences 22: 467–473.

Anene DO, Akter Y, Thomson PC, Groves P, Liu S, O'Shea CJ (2021) Hens that exhibit poorer feed efficiency produce eggs with lower albumen quality and are prone to being overweight. Animals 11.

Askan E, Dagdemir V, Tercan S (2018) Profitability analysis and marketing structure of green beans farms in Erzurum. Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi 8: 257-266.

Balcıoglu MS, Karabag K, Yolcu HI, Sahin E (2005). Japon bıldırcınlarında canlı ağırlığa göre iki yönlü seleksiyonun eşeysel olgunluk yaşı ve bazı verim özellikleri üzerine etkisi. *GAP*. IV. Agricultural Congress, 21–23 September, Sanlıurfa.

Guo Y, Zhao ZH, Ni Q, Chen XQ, Li Lx, Balasubramanian B, Jia RM, Liu WC (2021) Analysis of changing regulation of body weight and egg weight of Chinese indigenous goose (Shitou goose) in off-season breeding. The Journal of Animal & Plant Sciences 31:3, 918-922.

Hussain J, Akram M, Javed K, Ahmad HA, Mahmud A, Mehmood S, Ahmad S, Ahmad F, Jatoi AS, Abbas Y (2016) Quail breeder's production performance in response to selection for higher three weeks body weight. The Journal of Animal & Plant Sciences 26:3, 588-593.

Jatoi AS, Sahota AW, Akram M, Javed K, Jaspal MH, Mehmood S, Hussain J, Ishaq HM, Bughio E (2015) Egg quality characteristics as influenced by different body sizes in four close-bred flocks of japanese quails (coturnix coturnix japonica). The Journal of Animal & Plant Sciences 25: 921-926.

Kirici K, Cetin O, Gunlu A, Garip M (2004) Effect of hen weight on egg production and some eqq quality characteristics in Pheasants (Phasianus colchicus). Asian-Australasian Journal of Animal Sciences 17:5, 684-687.

Kumar D, Raginski C, Schwean-Lardner K, Classen HL (2018) Assessing the response of hen weight, body composition, feather score, egg quality, and level of excreta nitrogen content to digestible balanced protein intake of laying hens. Canadian Journal of Animal Science 98: 619-630.

Lacin E, Yıldız A, Esenbuga N, Macit M (2008). Effects of differences in the initial body weight of groups on laying performance and egg quality parameters of lohmann laying hens. Czech Journal of Animal

Science 53: 466-471.
Leeson S, Caston L, Summers JD (1997) Layer performance of four strains of leghorn pullets subjected to various rearing programs. Poultry Science 76: 1–5.
Monira KN, Salahuddin M, Miah G, (2003) Effect of breeding and holding period of egg characteristics of chicken. International Journal of Poultry Science 2: 261-263.
Muir WI, Akter Y, Bruerton K, Groves PJ (2022a) An evaluation of bird weight and diet nutrient density during early lay on ISA Brown performance, egg quality, bone characteristics, and liver health at 50 weeks of age. Poultry Science 101.
Muir WI, Akter Y, Bruerton K, Groves PJ (2022b) The influence of hen size and diet nutrient density in early lay on hen performance, egg quality and hen healty in late lay. Poultry Science 102041.
Najib H, Al-Yousif Y (2014) Egg size Saudi local layers as affected by line of the bird (body weight at sexual maturity) and Dietary fat level. International Journal of Poultry Science 13:8, 442-448.
Nazlıgul A, Turkyılmaz K, Bardakcıoglu EH (2001) A study on some production traits and egg quality characteristics of Japanese quail. Turkish Journal of Veterinary and Animal Sciences 25: 1007-1013.
Oke UK, Herbert U, Nwachukwu EN (2004) Association Between Body Weight and Some Egg Production Traits in the Guinea Fowl (*Numida meleagris galeata Pallas*). Livestock Research for Rural Development 16: 9.
Saleem MM, Hussain J, Elahi U, Khan EU, Usman M, Hashmi SGMD, Ahmad S (2022) Interactions effects of age and body weight losses during moulting on the performance of commercial laying hens. Turkish Journal of Veterinary and Animal Sciences 46: 1-8.
Sarıca M, Testik A (1993) Beyaz yumurtacı yerli otosex hibritlerin yumurta kalite özellikleri üzerine bir araştırma. Uluslararası Tavukçuluk Kongresi. 13–14 Mayıs 1993, Istanbul.
Seker I, Kul S, Bayraktar M, Yıldırım O (2005) Effect of layer age on some egg quality characteristics and egg production in Japanese quail. Journal of The Faculty of Veterinary Medicine Istanbul University 31: 129-138.
Stadelman WJ (1977) Quality preservation of shell eggs. In Egg Science and Technology. 2nd ed. W.J. Stadelman and O.J. Cotterill, ed. AVI publ. Co., Inc., Westport, CT.
Turkmut L, Altan O, Oguz I, Yalcın S (1999) Japon bıldırcınlarında canlı ağırlık için yapılan seleksiyonun üreme performansı üzerine etkileri. Turkish Journal of Veterinary and Animal Sciences 23: 229–234.
Yıldız O, Dagdemir V (2017) Sakarya ilinde fındık üretim maliyeti. Tarım Ekonomisi Dergisi 23: 37-42.