Effects of a Non-Fasting Moulting Treatment and Extended Cold Storage on Some Egg Quality Traits of a Commercial White Laying Hen

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***Abstract.** This study was aimed at investigating the effects of non-fasting moulting treatment and extended cold storage on table egg quality traits of a commercial white layer hen. For this research, 360 eggs were collected from moulted and non-moulted flock four weeks after the end of the moulting program. The hens in each group were allowed ad libitum access to water and their respective diets as grain barley for the moulting group and standard layer feed for the control group during the moulting period of 10 days and then a complete layer ration after the moulting program through the laying period. Sample eggs of each of these two groups were numbered, weighed and further assigned to a different storage period as daily fresh eggs: 15, 30, 45, 60 and 75 days. All eggs were stored between 4°C and 5°C and 55% and 60% relative humidity throughout the experiment. Egg weight, egg length, egg width, shell strength, shell weight, shell thickness, yolk height, yolk diameter, yolk colour, albumen height, albumen width, and albumen length were measured at each consecutive analysis period for egg quality comparison. Non-fast moulting treatment significantly affected egg weight, egg-width, egg length and breaking strength ($P < 0.001$, $P < 0.001$, $P < 0.001$ and $P < 0.020$). There were no significant effects of the length of a cold storage period on the external quality traits of egg weight, egg width, egg length and egg-shape index. Shell thickness and breaking strength of eggs were affected significantly ($P < 0.001$ and $P < 0.02$) by the length of a storage period. The yolk height and yolk colour scores were found to be significantly greater in eggs from the moulting group while all internal quality characteristics were significantly affected by the length of a storage period ($P < 0.001$). In conclusion, even if it was cold storage, egg quality tended to decline in the extended storage period and non-fasting moulting treatment improved the external and internal egg quality.*

Introduction

Induced moulting is a management application to extend the productive life of laying hen (Zhang et al., 2022). Moulting treatment generally improves post-moult productive performance, egg weight, egg quality and results in increases in percentage of A or AA grade eggs (Kakhki et al., 2018; Mishra et al., 2022; Lei et al., 2023; Wang et al., 2023). In practice, there are lots of moulting methods influencing body weight loss, mortality rate, post-moult egg production and egg mass of laying hens (Kakhki et al., 2018; Ga et al., 2022). An ideal moulting program should be providing good layer welfare and bird health without causing much stress and without feed-removal (Mishra et al., 2022). Currently, there is a big concern against conventional feed and water removal moulting methods due to greater body weight losses and higher mortality rates (Mishra et al., 2022). The feed removal also causes much more stress on hen body and declines immunity (Fard et al., 2020). As a result of increasing consumer awareness about animal welfare, egg producers from The United States, The United Kingdom and some European countries have decided to sell eggs produced only through non-feed withdrawal moulting programs (Mishra et al., 2022) and have adopted non-fasting moulting methods in commercial egg production. Non-fasting moulting is less stressful to hens, causes less liver damage, and improves second period production performance of hens by ensuring good animal welfare of animals (Fard et al., 2020; Lei et al., 2023). Zinc-based poultry diet has been one of the most popular non-fast moulting treatments in egg production. But the use of zinc in poultry feed should be strictly regulated due to the environmental effects of zinc (Ga et al., 2022). Therefore, non-fasting moulting treatments as alfalfa (Petek & Alpay, 2008) and whole wheat diets (Mishra et al., 2022) are getting popular in both table or breeder egg production. These diets can be economically acceptable and allow hens to meet their maintenance requirement. Non-feed removal moulting programs based particularly on whole grain barley have a positive effect on egg quality traits especially in yolk colour and Haugh unit (Petek et al., 2008; Onbaşılar et al., 2020).

With an extended laying period, egg production and eggshell quality tend to decline while egg weight increases (Alfonso Carrillo et al., 2021; Benavides-

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Reyes et al., 2021). Egg quality of end of layer hens can rapidly undergo quality deterioration during storage than that of younger birds, causing a major economic loss to the poultry industry (Nasri et al., 2019). The rate at which these changes occur during storage depends on several factors as temperature, humidity, length, etc. (Kopacz & Drazpo, 2018; Mishra et al., 2022). In general, longer period storage of eggs results in a decrease of albumen height, influences yolk and blastoderm quality, gas exchange and embryonic metabolism (Feddern et al., 2017; Quan et al., 2021). Eggs from older hens are more susceptible to longer period storage (Poletti & Vieira, 2021) as it reduces their shelf life and freshness of eggs. Freshness and shelf life of eggs, which are the most important quality characteristics, are a major concern of consumers. There are many factors contributing to the extended of shelf life of table eggs (Addo et al., 2018). Packing eggs under modified atmosphere and covering with shrink film may increase their shelf life (Petek et al., 2014; Giampietro-Ganeco et al., 2015). The main criteria of freshness are Haugh unit, egg weight loss and egg air cell size (Quan et al., 2021). Studies have shown that storage of eggs in a refrigerator or cold conditions will retain their nutritional value longer compared to room storage conditions (Faris et al., 2011; Nadia et al., 2012). The storage method had a significant effect on most egg quality traits, and eggs stored at 4°C were of good quality and were even classified as extra class eggs even after 28 days (Kopacz & Drazpo, 2018). If eggs storage in room temperature it's quality rapidly declines compare to cold storage (Jones et al., 2018). The main factors influencing internal egg quality are length and temperature of a storage period, and there is a significant interaction between both these factors (Grashorn et al., 2016; Feddern et al., 2017; Malfatti et al., 2021). There are a lot of research evidence about the effects of moulting and a storage period on post-moult laying performance and egg quality of both commercial layer and breeder hens. However, there is almost no research about the effects of an extended storage period for more than one month on post-moult egg quality. Therefore, this study was planned to compare the effects of an extended cold storage period on internal and external quality of table eggs collected from non-fast moulted and non-moulted commercial laying hens.

Material and Methods

The eggs for this research were collected from a moulted and a non-moulted flock housed in Research and Experimental Farm of the Faculty of Veterinary Medicine in Bursa Uludag University in Türkiye. This study did not require ethical permission according to Animal Experiments Ethics Committees Regulation on Working Procedures and Principles, Article 8 19-k (Official Gazette, 2014).

Eggs and management of the flocks

A total of freshly laid 360 eggs from moulted (180 eggs) and non-moulted flocks (180 eggs) were collected randomly for this research. The hens (Nick Brown) in both flocks were 70-week-old and they were the optimum age for moulting (Hy-Line International Technical Update, 2019) with similar body weights and laying rates. They were provided ad libitum access to a complete layer ration and water for a period of two weeks to assure that all hens were healthy and in active production before the moulting process. After the acclimation process, the hens were randomly divided into two treatment groups as non-fast moulting groups with 100% whole grain barley and non-moult control with a commercial layer ration. All birds in each group were allowed ad libitum access to water and their respective diets (whole grain barley for the moulting group and standard layer feed for the control group) during the moulting period for 10 days and then a complete layer ration after the moulting program. A commercial layer diet including 16.45% CP and 2800 ME kcal/kg for the hens was used from the acclimation period to the end of the laying period in the experiment. Light was provided 16 L:8 D in the pre- and post-moulting periods and was reduced to 11 hours (only natural light) during the moulting period. Both flocks were kept in the same house throughout the study period, under the same feeding and management conditions, except for the moulting period.

The eggs were collected by 4 weeks after the end of the moulting and transferred to the Egg Quality Laboratory. At arrival in the Egg Quality Laboratory of the University of Bursa Uludag, the eggs were assigned to each of six storage lengths (0, 15, 30, 45, 60 and 75 days) according to the moulting process as non-moulting and non-fast moulting (2 x 6 : 12 interactive groups). Standard home type refrigerators were used for the storage of eggs. All eggs in the control and moulting groups were kept in between 4°C and 5°C and 55% and 60% humidity conditions for all treatments. The storage temperature was slightly under the advice by the EU regulation EG 589/2008, which defines 5°C as the minimum storage temperature for eggs (Grashor et al., 2016). All tests were completed immediately after egg removal from the refrigerator on each target day.

Data

The first analysis was carried out on the first day after oviposition for fresh eggs. At this age, the eggs should qualify as "extra fresh" according to Turkish Food Codex on Egg and Egg Products (2008). Measurements on each egg included egg weight, egg width, egg length, shell thickness, breaking strength, yolk diameter, yolk height, albumen height, albumen width, albumen length and yolk colour. Eggs were weighed with a precision digital scale (0.01 precision). After weighing, the width (*along the equatorial axis*) and length (*along the longitudinal axis*) of the eggs were measured with a caliper to 0.1 mm. The egg shape index was determined from these measurements according to Anderson et al. (2004) as given with the formula: *width/length x 100*. The breaking strength of eggshell was measured with an eggshell force gauge and breaking point (Balnave & Muheereza, 1997) recorded as Newton (N) force required to crack the shell surface. After all eggs were broken on to a glass flat surface, the height of the albumen was measured with a tripod micrometer. A caliper was used to measure the length and width of albumen of eggs. The color of the yolk was determined using a color fan (DSM, 2022). Shell thickness (without inner and outer shell membranes which were removed manually) was measured at three areas (broad end, middle portion and narrow end of the shell), by using a micrometer according to Chowdhury (1990). The Haugh unit was calculated from the records of albumen height and egg weight using the following equation (Haugh 1937):

$$HU = 100.Log (H-1.7W^{0.37}+7.6)$$

Where HU is the Haugh unit, H is albumen height (mm), and W is egg weight (g).

Statistical analysis

The collected data were statistically analysed using SPSS 18.0 statistical package (SPSS Inc. 2018). All data were subjected to using two-way analysis of variance (ANOVA) with moulting process (*moulted and non-moulted*) and storage duration (*0, 15, 30, 45, 60 and 75 days*) as the main effects and all interactions between the two effects (Snedecor & Cochran, 1994). In all used statistical tests, differences at $P < 0.05$ were considered as significant.

Results

Some exterior egg quality traits in the experimental groups are presented in Table 1. Moulting treatment

Table 1. Some exterior egg quality traits in the experimental groups (mean ± SEM)

Groups	Egg weight (g)	Egg width, mm	Egg length, mm	Shell thickness, (mm/100)	Egg shape index, (%)	Breaking strength, (N)
Moulting (M)						
Control (C)	67.9 ± 0.58	45.0 ± 0.15	61.8 ± 0.26	36.4 ± 0.33	72.8 ± 0.35	28.9 ± 0.07
Moulting (M)	74.1 ± 0.59	46.1 ± 0.14	64.0 ± 0.25	34.9 ± 0.32	72.3 ± 0.34	30.9 ± 0.08
Storage Length (SL)						
Fresh	73.1 ± 0.90^{a}	45.5 ±0.25	63.3 ± 0.44	38.2 ± 0.004^{a}	72.0 ± 0.56	31.6 ± 1.34^{a}
15 d	71.9 ± 1.00^{a}	45.5 ±0.27	62.5 ± 0.47	37.5 ± 0.003^{a}	72.9 ± 0.59	30.8 ± 1.42^{a}
30 d	71.3 ± 1.09^{ab}	45.5 ±0.26	62.8 ± 0.48	36.6 ± 0.004^{a}	72.5 ± 0.62	30.9 ± 1.48^{a}
45 d	70.6 ± 1.08^{bc}	45.9 ±0.25	63.0 ± 0.44	35.5 ± 0.005^{a}	72.9 ± 0.56	30.0 ± 1.34^{a}
60 d	70.0 ± 0.90^{bc}	45.4 ±0.25	62.7 ± 0.44	32.5 ± 0.005^{b}	72.4 ± 0.57	28.4 ± 1.37^{b}
75 d	69.0 ± 1.00^{c}	45.5 ±0.24	63.2 ± 0.48	33.3 ± 0.006^{b}	72.4 ±0.59	25.5 ± 1.43^{b}
Moulting x Storage Length						
Cx0 d	69.8 ±1.33	44.9 ±0.35	62.3 ± 0.60	39.6 ± 0.008	72.0 ± 0.77	31.1 ± 1.82
Cx15 d	68.6 ±1.54	44.9 ±0.40	60.9 ± 0.69	38.8 ± 0.009	73.8 ± 0.89	30.0 ± 1.97
Cx30 d	67.9 ±1.42	44.6 ±0.37	61.2 ± 0.64	38.0 ± 0.008	73.0 ± 0.82	30.6 ± 1.97
Cx45 d	67.6 ± 1.42	45.6 ± 0.37	62.4 ± 0.64	36.0 ± 0.009	73.2 ± 0.82	29.2 ± 1.96
Cx60 d	66.9 ± 1.42	44.4 ± 0.37	60.9 ± 0.64	33.0 ± 0.009	72.9 ± 0.82	27.6 ± 1.97
Cx75 d	66.6 ± 1.38	45.5 ± 0.36	62.8 ± 0.62	32.8 ± 0.008	72.4 ± 0.80	24.7 ± 1.90
Mx0 d	76.4 ± 1.43	46.3 ± 0.36	63.8 ± 0.64	36.8 ± 0.008	72.6 ± 0.82	32.1 ± 1.97
Mx15 d	75.1 ± 1.38	46.1 ± 0.37	64.1 ± 0.62	36.1 ± 0.008	72.1 ± 0.80	31.6 ± 1.90
Mx30 d	74.7 ± 1.61	46.3 ± 0.42	64.4 ± 0.69	35.2 ± 0.007	72.1 ± 0.93	31.3 ± 2.22
Mx45 d	73.5 ± 1.34	46.2 ± 0.35	63.7 ± 0.64	35.1 ± 0.008	72.6 ± 0.77	30.8 ± 1.84
Mx60 d	73.1 ± 1.38	46.3 ± 0.36	64.5 ± 0.64	32.1 ± 0.008	72.0 ± 0.80	29.3 ± 1.90
Mx75 d	71.4 ± 1.54	45.5 ± 0.40	63.6 ± 0.72	33.9 ± 0.008	72.4 ± 0.89	26.2 ± 2.13
ANOVA						
M	0.001	n.s	n.s	n.s	n.s	0.02
SL	0.05	n.s	n.s	0.001	n.s	0.05
M x SL	n.s	n.s	n.s	n.s	n.s	n.s

n.s. non-significant

a-c; a-b; within the same columns, values with different superscripts were found significantly different significantly affected the egg weight and breaking strength of egg ($P < 0.001$ and $P < 0.020$) whereas egg weight, shell thickness and breaking strength were affected significantly ($P < 0.05$, $P < 0.001$ and $P < 0.020$) by the length of storage. There were no significant moulting x storage length interactions for all exterior egg quality traits investigated.

Mean and standard errors of some internal egg quality traits in the groups are shown in Table 2. There were significant differences for yolk height and yolk colour score between the control and moulting groups ($P < 0.001$ and $P < 0.001$). All internal quality traits investigated were found to be significantly different due to the effects of the length of the storage period ($P < 0.001$, $P < 0.002$, $P < 0.029$). No moulting x storage length interaction on all interior egg quality traits was observed.

Discussion

Induced moulting extends the productive life of a layer flock by improving egg production, shell quality, and albumen height of eggs (Hy-Line International Technical Update, 2019; Lei et al., 2023). Improved egg shell contributes to saving the internal egg quality, especially in the extended storage condition. Storage conditions used to store the eggs can have a major impact on both table egg or breeder egg quality and the subsequent viability of chicken embryos (Adriansen et al., 2022). Similarly, to some previous findings (Petek, 2001; Flock, 2016;

Table 2. Effects of moulting practice and length of egg storage on internal egg quality traits during the post-moult laying period (Mean ± SEM).

Groups	Yolk diameter, mm	Yolk height, mm	Albumen length, mm	Albumen width, mm	Albumen height, mm	Yolk color score	Haugh unit
Moulting (M)							
Control (C)	44.3 ± 0.31	17.4 ± 0.14	104.2 ± 1.37	82.3 ± 1.12	6.27 ± 0.15	10.9 ± 0.61	73.0 ± 1.45
Moulting (M)	44.9 ± 0.32	18.4 ± 0.15	106.4 ± 1.39	81.7 ± 1.14	6.63 ± 0.16	11.2 ± 0.62	74.2 ± 1.48
Storage Length (SL)							
Fresh	42.4 ± 0.52^{c}	18.6 ± 0.25^{a}	96.8 ± 2.30^{b}	75.7 ± 1.88^{c}	8.54 ± 0.25^{a}	10.9 ± 0.10^{b}	88.0 ± 2.44^{a}
15 days	43.5 ± 0.56^{bc}	18.4 ± 0.26^{a}	103.2 ± 2.43^{b}	80.2 ± 1.99^{bc}	6.79 ± 0.26^{b}	11.2 ± 0.11^{ab}	75.2 ± 2.59^{b}
30 days	43.4 ± 0.58^{bc}	19.4 ± 0.27^{a}	98.9 ± 2.54^{b}	81.4 ± 2.06^{ab}	6.01 ± 0.28^{c}	10.9 ± 0.11^{b}	68.7 ± 2.69^{b}
45 days	46.9 ± 0.52^{a}	17.8 ± 0.24^{b}	111.2 ± 2.30^{a}	83.1 ± 1.88^{ab}	5.86 ± 0.25^{c}	11.0 ± 0.10^{ab}	70.9 ± 2.44^{b}
60 days	44.3 ± 0.53^{b}	16.9 ± 0.25^{c}	110.4 ± 2.34^{a}	86.3 ± 1.91^{a}	5.77 ± 0.26^{c}	11.3 ± 0.10^{a}	70.5 ± 2.49^{b}
75 days	47.2 ± 0.56^{a}	16.4 ± 0.26^{c}	111.3 ± 2.44^{a}	85.3 ± 1.99^{a}	5.72 ± 0.28^{c}	11.3 ± 0.11^{a}	68.5 ± 2.59^{b}
Moulting x Storage length							
Cx0	42.7 ± 0.72	18.4 ± 0.34	99.6 ± 3.14	78.3 ± 2.56	8.00 ± 0.35	10.9 ± 0.14	86.4 ± 3.34
Cx15	42.4 ± 0.82	17.4 ± 0.40	98.4 ± 3.63	80.9 ± 2.96	6.84 ± 0.40	11.2 ± 0.16	79.4 ± 3.86
Cx30	43.5 ± 0.77	18.8 ± 0.36	97.8 ± 3.36	83.9 ± 2.74	5.38 ± 0.38	10.9 ± 0.15	62.6 ± 3.57
Cx45	46.0 ± 0.77	17.4 ± 0.36	114.1 ± 3.36	83.3 ± 2.74	5.59 ± 0.38	10.9 ± 0.15	69.8 ± 3.57
Cx60	43.6 ± 0.77	16.7 ± 0.36	105.4 ± 3.36	81.9 ± 2.74	5.98 ± 0.38	10.9 ± 0.15	73.0 ± 3.57
Cx75	47.4 ± 0.74	15.8 ± 0.35	109.8 ± 3.25	85.3 ± 2.64	5.81 ± 0.35	10.9 ± 0.14	67.5 ± 3.45
Mx0	42.1 ± 0.77	20.0 ± 0.36	94.0 ± 3.36	73.1 ± 2.74	9.08 ± 0.38	10.9 ± 0.15	89.5 ± 3.57
Mx15	44.5 ± 0.74	19.4 ± 0.35	108.0 ± 3.25	79.5 ± 2.65	6.75 ± 0.36	11.1 ± 0.14	70.6 ± 3.45
Mx30	43.2 ± 0.86	18.9 ± 0.40	100.0 ± 3.80	78.8 ± 3.09	6.64 ± 0.42	10.9 ± 0.17	74.8 ± 4.03
Mx45	47.7 ± 0.72	18.1 ± 0.34	108.4 ± 3.14	82.8 ± 2.56	6.14 ± 0.35	11.2 ± 0.14	72.9 ± 3.34
Mx60	45.0 ± 0.74	17.2 ± 0.35	115.4 ± 3.25	90.7 ± 2.65	5.55 ± 0.36	11.7 ± 0.14	67.9 ± 3.45
Mx75	47.1 ± 0.83	17.1 ± 0.39	112.8 ± 3.63	85.3 ± 2.96	5.64 ± 0.40	11.6 ± 0.16	69.5 ± 3.34
ANOVA							
M	n.s	0.001	n.s	n.s	n.s	0.001	n.s
SL	0.001	0.001	0.001	0.002	0.001	0.029	0.001
MxSL	n.s	n.s	n.s	n.s	n.s	n.s	n.s

n.s. non-significant
a–c; a–b; within the same columns, values with different superscripts were found significantly different for moulting and storage period.

Hy-Line Technical Update, 2019), as expected, the application of moulting improved the post-moult egg weight and egg weight related parameters such as egg breaking strength. But there was a decrease in egg shell thickness when the storage period was longer than regular. In another study, it was reported that moulting programs had a significant effect on the post-moult egg weight but there were no significant differences among control and moulting treatments for shape index, specific gravity, shell strength (Aygün & Yetişir, 2014). The bird fed with alfalfa hay for moulting had a greater egg weight, whereas pumice stone did not show any significant difference between the egg quality traits of moulted layers (Son et al., 2022).

Eggshell quality is very crucial in commercial production because of the economic losses of cracked or damaged eggs which account for 6% to 8% of total egg production (Hamilton et al., 1979). Egg breaking strength and shell thickness are the most important indicators of egg shell quality. Besides the total number of eggs, the shell quality also determines the number of saleable table eggs that a hen will lay in a lifetime period. In this study, there were no significant differences between the moulting and non-moulting groups for the egg shell thickness. But the shell thickness of eggs was significantly decreased with a prolonged storage period. During storage, shell thickness values of the eggs reduced from 36.6 to 29.6 mm. As a result of decreasing egg shell thickness, the breaking strength of egg shells also significantly decreased with a prolonged storage period. The shell breaking strength in the group fed with the moult induced-diet was significantly higher than that in the control birds fed normal layer diet ($P < 0.02$).

When the eggs collected from both moulted and non-moulted hens were analysed there was a significant variance in breaking strength values ($P < 0.02$). The egg shell of hens from the moulting group looked stronger than the eggs of hens from the non-moult control group. The length of the storage period also significantly influenced the breaking strength of eggs ($P < 0.05$). If we compare the shell strength of eggs in different storage period groups, eggs in all groups had a similar value until 45 days of storage. The eggs in the longer storage period than 45 days had a statistically weaker egg shell. The breaking strength value was the greatest on day 0 (31.6 N), and the lowest on day 75 (25.5 N). The breaking strength values measured in all interactive groups (moulting x storage period) ranged from 24.7 N to 32.1 N. In practice, there is no universal standard for the egg breaking point. But in general, a breaking point of 3.5 kgf (1 kgf to 9.80665 N) or higher has a strong, good enough and healthy shell that will endure most of the shipping and transportation vibrations or shocks that eggs endure (Mikesell, 2021). According to this reference, eggs in all groups had a weak breaking point. A greater breaking strength value signifies a stronger egg shell, which is ideal as the shell provides a protective barrier for the egg contents. In this study, there were no significant effects of moulting practice and length of the cold storage period on the shape index of eggs. The shape index value of all eggs in the groups was found to be between acceptable values of 72–76 (Sarıca & Erensayın, 2009).

All internal egg quality traits measured in this study were affected significantly by the length of the storage period. Similarly, to the findings of Aygün and Yetişir (2014), there were no significant differences for the post-moult albumen height and Haugh units (HU) of eggs among moulted and non-moulted hens. Otherwise, there was a distinct decrease in the HU of eggs after 15 days of storage and it remained stable after this time throughout the storage. This was concurrent with the findings of Grasshorn et al. (2016) who reported that Haugh units decreased with increasing storage duration. Jones and Musgrove (2005) showed that the HU initially was 88.00 and decreased to 68.50 by day 75. At the same time, the decline in albumen height and the HU resembles the results reported by Silversides and Villeneuve (1994). According to USDA-Agricultural Marketing Service guidelines (USDA, 2000), the white of eggs is described as firm (AA grade eggs) if they receive a score of 72 HU or higher and reasonably firm (A grade eggs) if they receive a score of 60–72 HU (Hisasaga et al., 2020). In this study, the average HU values of eggs from moulted and non-moulted hens can be classified as AA grade eggs. In general, the egg grade after 15 days of storage declined to A grade. Similar to our findings, Jones et al. (2002) reported a decline to grade A in HU values at 6 weeks in control eggs for a study conducted at refrigerated temperatures. Kralik et al. (2014) showed that the storage period was significantly affected ($P < 0.05$) albumen height and HU values of eggs. The decline of the Haugh units can also be considered an indicator of reduced lysozyme activity (Trziszka, 1994), known as an important agent to protect the egg contents against microbial contamination. The Haugh unit is an indicator of albumen quality (Haugh, 1937) and albumen quality is recognized as one of the major factors in measuring egg quality (Obianwuna et al., 2022). In another study, Hassan (2013) showed that storage length affected all egg quality traits and refrigerated eggs were able to maintain their quality comparable to the fresh eggs. In another study, Hamidu et al. (2017) reported that table egg quality as measured by the Haugh unit was not affected by oil preservation but quality decreased with increasing storage duration. In that study, it was found that within the first 28 days of storage the changes in egg weight, Haugh units and air cell size were not critical if eggs were kept at 6°C, but there was a rapid loss of quality at storage temperatures of 15°C and 22°C, especially in the Haugh unit. Foreman et al. (2023) reported that the eggs from the moulted Sasso breeder hens had a higher albumen height and haugh unit. In our study, there were no significant differences for the albumen height of eggs but a decrease was observed with the prolonged storage period, as expected (Quan et al., 2021). The average albumen heights of the eggs from moulted and non-moulted hens were 6.63 mm and 6.27 mm whereas the height was found to be 8.54 mm in fresh eggs and and 5.72 mm in eggs stored 75 days. In agreement with our study, Son et al. (2022) reported that albumen height of eggs varied within 6.07–6.43 in commercial laying hens. Another research showed that albumen height decreased from 7.05 to 4.85 mm compared to day 1 and week 10 of the extended cold storage (Jones & Musgrove, 2005).

In this study, the increase in yolk height and yolk colour score of post-moult hen eggs was found to be similar with the previous observations of Attia et al. (1994). The yolk colour scores in all groups were found to be greater than those reported by Son et al. (2022) who found these to be between 7.50 and 8.40 in commercial laying hens. The yolk height was increased in the moulting group because of the greater egg weight of post-moult layer hens while it was significantly decreased due to the length of egg storage, especially longer than 45 days of storage. The yolk colour score of the eggs was found to be statistically different in storage length groups. The improvement of yolk parameters after moulting may be due to rejuvenation of laying hen reproductive organs, as well as in broiler breeders (Brake & Thaxton, 1979; Berry & Brake, 1985; Verheyen et al., 1987). In general, yolk colour is brightening with increasing hen age and genotype has a significant effect on egg yolk colour (Nolte et al., 2021).

Conclusion

A whole grain barley-based diet is a high fibre diet and may be useful as a non-fasting moult feed. But palatability and nutritional value of this feed are comparatively low. Supplementation of a high fibre diet with different enzymes may improve feed digestibility and nutrient availability of this moult diet. Non-fasting moulting treatment used in this study increased external egg quality by increasing the egg weight and breaking strength. Almost all internal egg quality values deteriorated with the prolonged storage period. Egg grade has been declined from AA to A after 15 days of storage. Eggs that need to be stored for a long time should be stored under the conditions recommended by the regulations and should be consumed in a short period as much as possible.

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