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Effect of temperature and storage time on the quality of eggs from commercial laying hens

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SUMMARY

The study aimed at assessing the quality of commercial laying hen eggs stored under different temperatures and storage periods. 440 eggs were collected soon after laying by DeKalb White laying hens. All eggs were identified, weighed, and randomly distributed in trays, being 200 stored at room temperature (25.8 ± 0.9 °C), 200 other placed in trays under refrigeration (7.0 ± 0.4 °C), and the the other 40 eggs were used to carry out the evaluation on the first day. The trial design was completely randomized 2x11, scheme factorial, with two temperatures and 11 storage periods (one, three, six, nine, 12, 15, 18, 21, 24, 27, and 30 days), with 20 repetitions. The assessed variables were and egg weight loss, specific gravity, Haugh unit, albumen and yolk pH, yolk color, and percentage of shell, albumen, and yolk. The values of egg weight loss, specific gravity, Haugh unit, albumen and yolk pH, yolk color, and percentage of albumen and yolk were significantly influenced (P<0.05) by the storage temperature and period. The different storage temperatures and periods did not influence the percentage of shell in the eggs. It can be concluded that the eggs maintain excellent quality when stored for up to three days after laying, maintain a high-quality standard for up to six days of storage at room temperature, and maintain excellent quality when stored under refrigeration for up to 30 days.

Additional keywords

Specific gravity.
Albumen and yolk index.
Haugh unit.

Efeito da temperatura e período de armazenamento sobre a qualidade de ovos de poedeiras

RESUMO

Objetivou-se avaliar a qualidade de ovos de poedeiras comerciais armazenados em diferentes temperaturas e períodos de armazenamento. Foram coletados, logo após a postura, 440 ovos de poedeiras da linhagem Dekalb White. Todos os ovos foram identificados, pesados e distribuídos aleatoriamente às bandejas, sendo 200 armazenados em temperatura ambiente (25,8 ± 0,9° C), 200 ovos em bandejas sob refrigeração (7,0 ± 0,4° C) e os 40 ovos foram utilizados para realizar avaliação no primeiro dia. O delineamento utilizado foi inteiramente casualizado em esquema fatorial 2x11, sendo duas temperaturas de armazenamento e 11 períodos de estocagem (um, três, seis, nove, 12, 15, 18, 21, 24, 27 e 30 dias), com 20 repetições. Os valores de perda de peso, gravidade específica, Unidade Haugh, pH de albúmen e de gema, coloração da gema, porcentagem de albúmen e de gema dos ovos foram influenciados (P<0,05) pela temperatura e período de armazenamento. As diferentes temperaturas e períodos de armazenamento não influenciaram sobre a porcentagem de casca dos ovos. Concluiu-se que os ovos armazenados até três dias após a postura se mantêm em excelente qualidade, permanecendo em padrão de alta qualidade até seis dias de armazenamento em temperatura ambiente, e quando armazenados sob refrigeração mantêm padrão de excelente qualidade até os 30 dias.

Palavras chave adicionais

Gravidade específica.
Índice de albúmen e gema.Unidade Haugh.

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INTRODUCTION

The egg is one of the most complete and balanced foods and contain high levels of proteins, amino acids, fats, vitamins, and minerals. However, so that all this nutritive potential can be exploited by humans, eggs must be conserved over the marketing period since weeks can go by from the time the eggs are laid, purchased, and consumed (Pascoal et al., 2008).

The increase in egg consumption and the use of their nutritional qualities by the population depend on the quality of the product offered to consumers, which is determined by a set of characteristics that can influence the eggs' acceptability on the market. As all natural products of animal origin, eggs are also perishable and begin to lose their internal quality right after being laid in case appropriate measures for their conservation are not taken. Therefore, quality loss in eggs is an unavoidable phenomenon that takes place continuously over time and that can be worsened by several factors (Giampietro-Ganeco et al., 2015).

Two of the main factors influencing eggs' internal quality are storage time and conditions (Scott &

Silversides, 2000). During storage, alterations in the physical, chemical, and functional characteristics of the egg proteins can occur, but these alterations depend on a few factors such as storage time, temperature, and air relative humidity (Scott & Silversides; 2000; Pissinati, 2014).

The Quality Control Program recommended by the United States Department of Agriculture (USDA) defines the conditions to be maintained from the time the eggs are laid until they are consumed by the population. For that, eggs considered of excellent quality (AA) must have Haugh unit (HU) values above 72; high-quality eggs (A), between 60 and 72 HU; and lower-quality eggs (B), HU values below 60 (USDA, 2000). In Brazil quality aspects are evaluated by the Egg Identity and Quality Standard in Nature (BRASIL, 1991), mainly on the shell, air chamber, albumen and yolk. According to the conditions of each of these factors, the eggs can be classified into five quality classes: class A, B, C, D and E. As for weight, the egg is classified into six types: jumbo (minimum 66g / unit), extra (60 to 65g / unit), large (55 to 60g / unit), medium (50 to 55g / unit) and small (45 to 50g / unit). Eggs less than 45g can be used for industrialization (BRASIL, 1991).

With long storage, several quality features of the albumen and yolk are lost. The rate of changes in albumen and yolk is associated to the temperature and the movement of carbon dioxide of the albumen through the shell as a consequence of a negative concentration gradient (Biladeau & Keener, 2009; Khan et al., 2013). Refrigeration preserves the internal quality of eggs, which would be greatly favored if the eggs left the farms straight to the fridge where they would be kept at a temperature between 0 °C and 4 °C, thus guaranteeing to the consumer a healthy, nutritious, and tasty product which could be consumed safely. However, although Brazil is a tropical country, eggs are processed in the farms and arrive at points of sale at room temperature, and they remain under such condition throughout the marketing period (Barbosa et al., 2008). With this in mind, the study aimed at assessing the quality of eggs from commercial laying hen stored under different temperatures and for different storage periods.

Material and Methods

The trial was carried out in the Animal Nutrition Laboratory of the Center of Agrarian Sciences of the Federal University of Alagoas – UFAL, Brazil. A total of 440 eggs were collected soon after laying by Dekalb White laying hens. All eggs were identified, weighed on a precision scale, and next placed in cardboard trays holding three dozen eggs each. The eggs were randomly assigned to the trays, being 200 stored at room temperature, 200 under refrigeration, and 40 used for the assessment on the first day.

Over the trial period, the maximum and minimum temperatures of the storage areas were recorded daily at 10:00 am with a digital thermohygrometer. The average refrigeration temperature was 7.0 ± 0.4 °C and the room temperature was 25.8 ± 0.9 °C.

The trial design was completely randomized, scheme factorial, with two storage conditions (room temperature and refrigeration) and 11 storage periods (one, three, six, nine, 12, 15, 18, 21, 24, 27, and 30 days), with 20 repetitions. The assessed variables were egg weight loss, specific gravity, Haugh unit, albumen and yolk pH, yolk color, and percentage of shell, albumen, and yolk. In order to determine the eggs' total weight and egg weight loss, an analytical balance was used, being the eggs' weight the reference value for later calculating the percentages of each fraction of the eggs.

Specific gravity was determined by the saline solution flotation method according to the methodology described by Hamilton (1982). Next, the eggs were broken onto a flat smooth glass surface where the height of the dense albumen and yolk was measured, in millimeters, with a Digimes digital micrometer with resolution of 0.01mm/0.0005". From the height of the albumen and weight of the egg, the Haugh unit values were determined with the formula, , where HA = height of the albumen and W = weight of the egg in grams (Romanoff & Romanoff, 1963; Silversides et al., 1993).

In order to determine albumen and yolk pH, a pH meter Gehaka brand was used. For calculating the percentages of shell, yolk, and albumen, the following formulas were used respectively: ; ; .

For the variables studied, the differences between the means of the treatments were compared by the Student-Newman-Keuls test, at a significance level of 5%. Afterwards, the storage time factors at room temperature and under refrigeration were submitted to the regression analysis using the SAEG package version 9.0 (UFV, 2007).

RESULTS AND DISCUSSION

The eggs' weight loss was significantly influenced ($P<0.05$) by the different storage temperatures **(Table I)**. The eggs stored at room temperature had higher weight loss (1.85%) than the eggs kept under refrigeration, indicating the eggs' weight loss is influenced by both the temperature and the storage time. Similar results were obtained in the studies conducted by Barbosa et al. (2008) and Pissinati et al. (2014) who observed greater weight loss (9.20 and 3.77%, respectively) in eggs stored at 25 ° C. However, the effect of temperature was only noticed from the 9th day on for both the eggs stored at room temperature and under refrigeration, although this loss was more marked in the eggs kept at room temperature.

The eggs' weight loss was linearly influenced ($P<0.05$) as the storage period increased for both room temperature and refrigeration, following their respective equations: ($R^2=0.99$) and ($R^2=0.99$). This result was likely due to the transfer of humidity from the albumen to the outside of the egg through the shell, caused by the high temperatures of the eggs stored at room temperature, which possibly potentialized the weight loss during the first days of storage. These results corroborate those obtained by Jones and Musgrove (2005), Barbosa et al. (2008), Garcia et al. (2010), and Figueiredo et al. (2011) who found greater weight loss of eggs stored at room temperature.

Table I. Average values of weight loss (%), specific gravity, and Haugh unit of eggs from commercial laying hens stored for 30 days at room temperature and at refrigeration (Valores médios de perda de peso (%), gravidade específica e unidade Haugh de ovos de galinhas poedeiras comerciais armazenadas durante 30 dias à temperatura ambiente e na refrigeração).

Storage period (days)*	Weight loss (%)		Specific gravity		Haugh unit	
	25.8 °C	7.0 °C	25.8 °C	7.0 °C	25.8 °C	7.0 °C
1	0.00^{bD}	0.00^{bD}	1.0953^{aA}	1.0960^{aA}	100.42^{aA}	98.47^{aA}
3	0.32^{bD}	0.39^{bD}	1.0941^{aA}	1.0949^{aA}	80.41^{bB}	87.50^{aA}
6	0.79^{bD}	0.74^{bD}	1.0894^{aA}	1.0873^{aA}	68.76^{bB}	87.26^{aA}
9	1.24^{aC}	1.21^{bC}	1.0841^{aA}	1.0874^{aA}	58.27^{bB}	83.54^{aB}
12	1.52^{aC}	1.22^{bC}	1.0789^{bB}	1.0845^{aB}	52.41^{bC}	82.71^{aB}
15	1.88^{aC}	1.59^{bC}	1.0779^{bB}	1.0823^{aB}	46.34^{bC}	82.04^{aB}
18	2.18^{aC}	1.98^{bC}	1.0740^{bB}	1.0748^{aB}	45.38^{bC}	80.3^{aB}
21	2.74^{aB}	2.12^{bB}	1.0689^{bB}	1.0739^{aB}	41.73^{bC}	80.39^{aB}
24	2.95^{aB}	2.60^{bB}	1.0638^{bC}	1.0679^{aC}	34.70^{bD}	78.68^{aB}
27	3.12^{aA}	2.78^{bB}	1.0604^{bC}	1.0660^{aC}	29.38^{bD}	78.47^{aB}
30	3.58^{aA}	3.21^{bA}	1.0543^{bC}	1.0605^{aC}	28.71^{bD}	78.48^{aB}
Averages	1.85A	1.62B	1.0764B	1.0795A	53.32B	83.44A
p-value						
Storage period (SP)	<0.001		<0.001		<0.001	
Temperature (T)	<0.001		<0.001		<0.001	
SP *X* T	<0.001		<0.0029		<0.001	
CV (%)	16.85		0.50		9.60	

Averages followed by different letters, upper case and lowercase in the column and the line, respectively, for the same variable, differ by Student-Newman-Keuls test (P <0.05).
* Linear effect (P<0.05).

There was a significant (P<0.05) effect of temperature and storage period on the eggs' specific gravity. It was seen that eggs stored at room temperature had lower specific gravity values than those stored under refrigeration. From the 12th day of storage on, a marked reduction was seen in specific gravity values for both storage conditions, though the eggs stored at room temperature had lower results (1.0764) than the ones kept under refrigeration. Freitas et al. (2011) also found lower values of specific gravity (1.065) for eggs stored at room temperature compared to those stored under refrigeration (1.080).

The specific gravity values were linearly reduced (P<0.05) the longer the storage period for both eggs stored at room temperature and under refrigeration, according to the equations: (R^2=0.99) and (R^2=0.93), respectively. The reduction in specific gravity possibly happened because of the loss of water in the egg, right after laying, as a consequence of evaporation, which causes a progressive increase of the air chamber. Moreover, this reduction may be related to the eggs' weight loss during storage. These results are in accordance with those obtained by Barbosa et al. (2008) and Santos et al. (2009 Similar results were obtained by Freitas et al. (2011) observed a linear reduction of the specific gravity of the egg, estimated at around 0.0016 and 0.0007 units per day, at room temperature and refrigerated, respectively.

The Haugh unit values were influenced (P<0.05) by the different temperatures and storage periods. The eggs stored under refrigeration had higher average Haugh unit values, showing the benefit of using refrigeration to maintain the internal quality of eggs during storage. Similar results were obtained by Barbosa et al. (2008), Garcia et al. (2010), and Figueiredo et al. (2011). Is was noticed that from the 3rd day of storage on that the eggs stored at room temperature had a marked decrease in Haugh unit values, resulting in eggs of lower-quality (53.32).

The Haugh unit values linearly decreased (P<0.05) as the storage period increased for both eggs kept at room temperature and under refrigeration, following their respective equations: (R^2=0.91) and (R^2=0.75).

The eggs assessed on the day they were laid initially had Haugh unit values of 100.42 and, at 30 days of storage at room temperature, the value was 28.71, i.e., the eggs quickly lost quality, going from excellent quality

Table II. Albumen and yolk pH values and yolk color of eggs from commercial laying hens stored for 30 days at different temperatures (Valores de pH e gema de ovos de galinhas poedeiras comerciais armazenadas durante 30 dias em temperaturas diferentes).

Storage period (days) *	Albumen pH		Yolk pH	
	25.8ºC	7.0 ºC	25.8ºC	7.0ºC
1	7.84bC	7.82bC	5.72aB	5.72aB
3	8.79aB	8.64bB	5.78aB	5.78aB
6	9.02aB	8.79bB	5.81aB	5.79aB
9	9.16aB	8.90bB	5.80aB	5.80aB
12	9.15aB	8.90bB	5.84aA	5.80bA
15	9.31aB	8.96bB	5.85aA	5.80bA
18	10.22aA	9.86bA	5.85aA	5.79bA
21	10.19aA	9.86bA	5.88aA	5.81bA
24	10.25aA	9.91bA	5.88aA	5.83bA
27	10.21aA	9.93bA	5.89aA	5.85bA
30	10.19aA	9.83bA	5.92aA	5.84bA
Averages	9.48A	9.22B	5.84A	5.80B
p-value				
Storage period (SP)	<0.001		<0.001	
Temperature (T)	<0.001		<0.001	
SP *X* T	<0.001		<0.001	
CV (%)	1.26		0.81	

Averages followed by different letters, upper case and lowercase in the column and the line, respectively, for the same variable, differ by Student-Newman-Keuls test (P <0.05).
* Linear effect (P<0.05).

to a lower quality standard. Such response may be attributed to the reduction in albumen height due to its liquefying, a process that was sped up by the high temperatures during the trial period. The decline of the quality is mainly associated with the loss of water and carbon dioxide during the storage period, being proportional to the elevation of the ambient temperature. The albumen becomes more liquid as inadequate storage conditions persist. The continuous loss of carbon dioxide increases the alkalinity conditions inside the eggs, resulting in changes in taste and, consequently, the palatability of the product. In addition, during the storage period egg albumin is transformed into S-ovoalbumin and dissociation of the ovomucine-lysozyme complex occurs with the destruction of the ovomucin gel. These reactions are important because they cause the loss or reduction of the gelling and foaming properties of the viscosity of the albumen, making them liquefied and facilitates the evaporation of water through the shell's pores (Leandro et al., 2005; Barbosa et al. 2008; Freitas et al., 2011; Figueiredo et al., 2011).

On the other hand, the eggs stored under refrigeration had similar quality on the first and 30th days with average values of 98.47 and 78.48, respectively, remaining at the excellent quality standard according to the quality control recommended by the USDA (USDA, 2000), showing that storing eggs under refrigeration is essentially beneficial for their internal quality. These results match those obtained by Jones and Musgrove (2005), Barbosa et al. (2008), Xavier et al. (2008), Garcia et al. (2010), and Figueiredo et al. (2011).

The albumen and yolk pH values were significantly influenced (P<0.05) by the different storage temperatures and periods **(Table II)**. The eggs kept at room temperature had higher average albumen pH values than the ones kept under refrigeration. Similar results were obtained by Scott and Silversides (2000) and Figueiredo et al. (2011). When the albumen pH values increase, the Haugh unit values worsen and the eggs' taste change since the alkaline pH negatively influences the vitelline membrane.

It was seen that from the 3rd day of storage on the eggs had a marked increase in albumen pH values in both storage conditions, at 9.48 for the eggs stored at room temperature and 9.22 for those under refrigeration, confirming that storage temperature and time affect pH. In recently-laid eggs, the albumen pH normally ranges from 7.6 to 7.9; when they get older, carbon dioxide is released and the pH values reach 9.5

Table III. Shell, albumen, and yolk percentages in eggs from commercial laying hens stored for 30 days at different temperatures (Casca, albumina e gemas em ovos de galinhas poedeiras comerciais armazenadas durante 30 dias em diferentes temperaturas).

Storage period (days)	Shell percentage^{ns}		Albumen percentage*		Yolk percentage*	
	25.8 °C	7.0 °C	25.8 °C	7.0 °C	25.8 °C	7.0 °C
1	9.96	9.96	64.17^a	63.73^a	25.87	26.19
3	10.68	10.11	62.14^b	63.53^a	27.17	26.37
6	10.49	10.16	61.60^b	63.18^a	27.90	26.65
9	10.14	10.04	61.30^b	62.26^a	28.03	27.70
12	10.49	10.49	60.61^b	61.84^a	28.92	27.97
15	10.47	10.43	60.44^b	61.50^a	29.09	28.07
18	11.01	10.50	59.86^b	61.14^a	29.33	28.36
21	10.90	10.82	59.66^b	60.56^a	29.23	29.01
24	10.68	10.73	59.37^b	59.93^a	30.00	29.82
27	10.74	10.71	58.99^b	59.84^a	30.34	29.74
30	10.71	10.89	58.92^b	59.63^a	30.49	29.27
Averages	10.57	10.44	60.64B	61.56A	28.76	28.10
p-value						
Storage period (SP)	******		<0.001		<0.001	
Temperature (T)	******		<0.001		<0.001	
SP *X* T	******		<0.001		******	
CV (%)	6.51		2.84		6.23	

Averages followed by different letters on the column, for the same variable, are different according to Student-Newman-Keuls (P<0.05).
^{ns} não significativo (P<0.05).
* Linear effect (P<0.05).

(Stadelman & Cotterill, 1995; Brake et al., 1997; Alleoni & Antunes, 2001).

Albumen pH increased (P<0.05) linearly as a function of the longer storage period of eggs both at room temperature and under refrigeration, according to their respective equations: (R^2=0.86) and (R^2=0.85). The increase in pH occurred due to the dissociation of carbonic acid, which is one of the components of the albumen buffer system, forming water and carbon dioxide. This reaction is sped up with higher storage temperatures. Under natural conditions, the carbon dioxide formed diffuses through the shell and is released into the air and albumen pH rises, reducing its acidity. Similar results were found by Scott and Silversides (2000), Leandro et al. (2005), Xavier et al. (2008), Garcia et al. (2010), and Figueiredo et al. (2011).

It was seen that the eggs stored at room temperature had a greater increase in yolk pH values than those stored under refrigeration. However, the effect of temperature was only seen from the 12th day on for both the eggs stored at room temperature and under refrigeration, and this effect was more intense at 25.8 °C. This response happened due to the alkaline ions from the albumen that can be exchanged with the H^+ ions in the yolk with the increase in yolk pH. This pH variation could lead to protein denaturation and increase yolk consistency.

There was a linear increase (P<0.05) of yolk pH in both the eggs stored at room temperature and under refrigeration the longer the storage time, according to the following equations: (R^2=0.80) and (R^2=0.78), respectively. These results match those found by Solomon (1991) and Akyurek and Okur (2009), who saw an increase in yolk pH as a function of storage time. On the other hand, Garcia et al. (2010) found a quadratic effect for yolk pH values over the storage time of eggs.

The percentage of the eggs' shell was not significantly influenced (P>0.05) by the different storage temperatures and periods **(Table III)**. The eggs stored for 30 days, irrespective of the temperature, did not show significant differences (P>0.05) regarding the shell. These data match those found by Ramos et al. (2010), who saw no significant effect in the percentage of shell for eggs stored at different temperatures. Nevertheless, Santos et al. (2009), Garcia et al. (2010), and Figueiredo et al. (2011) found a higher proportion of shell in eggs the longer the storage time.

There was a significant effect ($P<0.05$) on the percentage of albumen and yolk in eggs kept under either temperature conditions and all storage periods. The albumen percentage in eggs stored under refrigeration had higher values than those kept at room temperature. The effect of temperature on the albumen percentage was seen only from the 3rd day on for both the eggs stored at room temperature and under refrigeration, an effect that became more pronounced at 25.8 °C.

Albumen percentage decreases ($P<0.05$) linearly as a function of the longer storage period of eggs both at room temperature and under refrigeration, according to the following equations: ($R^2=0.94$) and ($R^2=0.95$), respectively. The results obtained can be attributed to the transference of water from the albumen to the yolk through the vitelline membrane, causing a reduction in the albumen proportion over the eggs' storage period. These results match those found by Garcia et al. (2010) and Ramos et al. (2010).

There was no significant difference ($P>0.05$) on the values of yolk percentage in eggs stored at the different temperature conditions. However, the yolk percentage in eggs was linearly influenced ($P<0.05$) as the storage period increased for both room temperature and refrigeration, following their respective equations: ($R^2=0.77$) and ($R^2=0.83$). This increase in the yolk percentage begins right after the eggs are laid since at that moment there is a osmotic pressure gradient between the albumen and the yolk, which becomes progressively higher as the water goes from the albumen into the yolk, and this rate is higher at higher temperatures. Similar results were obtained by Barbosa et al. (2008) and Garcia et al. (2010).

CONCLUSIONS

It can be concluded that the eggs maintain excellent quality when stored for up to three days after being laid, maintain a high quality standard for up to six days of storage at room temperature, and maintain excellent quality when stored under refrigeration for up to 30 days.

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