BIA BOLETIM DE INDÚSTRIA ANIMAL

Qualidade de Produtos de Origem Animal

EFFECT OF STORAGE TIME AND TEMPERATURE ON THE QUALITY OF JAPANESE QUAIL EGGS

Yolanda Lopes da Silva
Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, PR, Brasil,
https://orcid.org/0000-0003-3546-3016
Email correspondente: ylopesdasilva@yahoo.com.br

Tatiane Fernandes
Universidade de Lisboa, Lisboa, Portugal,
https://orcid.org/0000-0002-9825-5735

Elaine Barbosa Muniz
Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, PR, Brasil,
https://orcid.org/0000-0001-7660-7683

Nilton Garcia Marengoni
Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, PR, Brasil,
https://orcid.org/0000-0002-0666-4567

Paulo Levi de Oliveira Carvalho
Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, PR, Brasil,
https://orcid.org/0000-0001-9273-3209

Nardel Luiz Soares da Silva
Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, PR, Brasil,
https://orcid.org/0000-0001-6760-1044

Submetido em: 22/07/2020
Aprovado em: 16/12/2020

Abstract

The objective of this work was to evaluate the effect of storage time and temperature on the quality of quail eggs. The experimental design was completely randomized in split plots, with two storage temperatures in the plots and six storage periods in the subplots. The variables analyzed were: egg weight; albumen and yolk weight, height and pH; Haugh units (HU); and yolk index and diameter. ¨The interaction between storage time and temperature was not significant (P>0.05) for egg weight, yolk weight and pH, but was significant (P<0.05) for albumen height, weight and pH, HU, and yolk diameter, height and index. The storage period had a quadratic effect in the two storage conditions for HU, albumen pH, yolk height and index, while for eggs stored at room temperature there was a quadratic effect on egg and albumen weight, albumen height, yolk weight, diameter and pH. In turn, for eggs kept under refrigeration, the effect of the storage period was linear for egg weight, albumen weight and height, yolk weight and pH. There was no effect in the regression analysis of the storage period for the yolk diameter of the eggs stored under refrigeration. The storage conditions influenced the egg weight and quality characteristics of the albumen and yolk, but had no effect on the yolk weight. Non-refrigerated eggs presented lower averages for all the characteristics except albumen pH, and yolk pH and diameter. During the entire storage period, the quality of the eggs without refrigeration remained lower than that of refrigerated eggs. Thus, to preserve quality, quail eggs should be stored under refrigeration.

Key words

Japanese quail, storage time, egg weight, egg quality, storage temperature

EFEITO DO TEMPO E DAS CONDIÇÕES DE ARMAZENAMENTO NA QUALIDADE DE OVOS DE CODORNAS JAPONESAS

Resumo

O objetivo do trabalho foi avaliar o efeito da temperatura e do tempo de estocagem na qualidade de ovos de codorna. O delineamento foi inteiramente casualizado em parcela subdividida, sendo duas temperaturas de armazenamento nas parcelas e seis períodos de estocagem nas subparcelas. As variáveis analisadas foram: peso do ovo, peso, altura, pH do albúmen e da gema, Unidades Haugh (UH), diâmetro e índice de gema. A interação entre período e temperatura de armazenamento não foi significativa (P>0,05) para o peso do ovo, pH e peso da gema. Contudo foi significativa (P<0,05) para altura do albúmen, peso, pH do albúmen, UH, diâmetro, altura e índice de gema. O período de estocagem teve efeito quadrático nas duas condições de estocagem para: UH, pH do albúmen, altura e índice de gema e para ovos armazenados em condições ambientes para: peso do ovo e do albúmen, altura de albúmen, peso, diâmetro e pH da gema. Para os ovos mantidos em refrigeração o efeito do período de estocagem foi linear para: peso do ovo e do albúmen, altura de albúmen, peso e pH da gema. Não houve regressão do período de estocagem para o diâmetro da gema dos ovos armazenados em refrigeração. As condições de estocagem influenciaram o peso do ovo e as características de qualidade do albúmen e da gema, porém não teve efeito sobre o peso da gema. Os ovos sem refrigeração apresentaram médias inferiores para a maioria das características exceto para o pH do albúmen, pH e diâmetro da gema. Durante todo o período de estocagem, a qualidade dos ovos sem refrigeração manteve inferior aos ovos refrigerados. Para preservar a qualidade, os ovos de codorna devem ser armazenados em refrigeração.

Palavras chaves

Codornas japonesas, período de estocagem, peso do ovo, qualidade de ovo, temperatura de estocagem.

INTRODUCTION

The rearing of laying quails has advantages due to their zootechnical characteristics of precocity, high prolificacy, low feed consumption, good disease resistance and excellent egg quality, besides the possibility of using manure as fertilizer. These advantages have attracted the interest of producers in recent decades, during which there has been a substantial increase in production of quail eggs in Brazil, except for 2016 when production declined to 273,419 thousand dozen after having expanded by 13.9% in 2015 to 447,468 thousand dozen. The leading producing states are São Paulo, Espírito Santo and Minas Gerais according to the Municipal Stock Breeding Survey (PPM) (IBGE, 2017).

Quail eggs can be consumed in conserves and fine baked goods, and as garnishes and appetizers.

Eggs in general are rich in essential nutrients. According to Panda and Singh (1990), quail eggs have average moisture content of 74.6%, protein of 13.1%, minerals of 1.1% and lipids of 11.2%. The levels of calcium, phosphorus, iron, vitamin A and energy in 100 g of quail eggs are 59 mg, 220 mg, 3.8 mg, 300 IU and 158 kcal, respectively. The consumption of six quail eggs (10 g/egg) per day is the same as one chicken egg (60 g).

To maintain the nutritional quality of quail eggs it is necessary to store them in adequate conditions, because they start to lose quality as soon as they are laid.

For proper conservation, quail eggs should be stored at temperature of 10 to 15 °C and relative humidity of 70 to 80%, besides being kept in places without strong odors, since they tend to absorb ambient smells (Lana, 2000).

Extensive storage periods reduce the internal quality of eggs. As time passes, the albumen becomes less viscous due to chemical reactions related to loss of water and carbon dioxide through the pores in the shell, causing a reduction of its height, increased alkalinity and loss of palatability (Moreng & Avens, 1990). Akpinar et al. (2015) also reported reduced internal quality of several parameters of quail eggs due to storage time.

According to Dada et al. (2018), the quality of quail eggs deteriorates rapidly when they are stored at ambient temperature, and they become improper for consumption after such storage for three weeks. The storage of eggs under refrigeration reduces the pace of this deterioration.

According to Nemati et al. (2000), normally the storage of eggs before incubation or consumption is inevitable, but this can affect their quality. Therefore, the storage temperature and time are important factors that affect the maintenance of quality of quail eggs.

In Brazil, the conditions for storage and sale of quail eggs are typically the same as those recommended for chicken eggs.

In this context, the present study had the objective of evaluating the effect of storage temperature and time on the quality of Japanese quail eggs.

MATERIAL AND METHODS

The experiment was conducted in the Food Technology Laboratory of the Center for Agrarian Sciences of Western Paraná State University (UNIOESTE), located in the municipality of Marechal Cândido Rondon in western Paraná.

The treatments consisted of the combination of two storage temperatures (ambient and refrigeration) and six storage periods (0, 7, 14, 21, 28 and 35 days).

The experimental design was completely randomized in a split-plot, with two storage temperatures (refrigerated and ambient) and six storage times (0, 7, 14, 21, 28 and 35 days), with four repetitions and 10 eggs per experimental unit, for total of 480 eggs.

The variables analyzed were related to egg weight and quality of the albumen and yolk. The albumen quality was assessed by the weight, height, pH and Haugh units (HU), while the yolk quality was determined by the weight, height, diameter, yolk index and pH.

The eggs were purchased on the day of arrival at the supermarket and were taken to the laboratory where they were weighed and placed in cardboard trays, distributed randomly among the respective treatments (combination of two storage temperatures and six storage periods).

To control the refrigeration temperature (5 °C ± 2 °C), the refrigerator was only opened at the moment of retrieving the eggs for analysis. The minimum and maximum ambient temperatures were measured daily and the averages were 14.08 °C and 38.7 °C.

On the days corresponding to each storage period, the eggs were weighed and then broken and emptied on a glass surface to determine the albumen and yolk quality measures.

The egg weight was measured on a semi-analytic digital scale with accuracy of 0.01 g. The albumen height, yolk height and diameter were determined (in millimeters) with a digital pachymeter. Soon thereafter, the yolk and albumen were carefully separated and transferred to beakers for weighing with the semi-analytic scale**.** Then they were homogenized with a glass stirrer for measurement of the pH with a digital pH meter.

The albumen weight was calculated by the difference between the egg weight and the sum of the yolk and shell weight. The yolk index was determined by the ratio between the yolk height and diameter, expressed as a percentage.

The Haugh units were calculated according to the equation: HU= 100 log $(H+7.57-1.7W^{0.37})$, where H is albumen height (mm); W is egg weight (g); 7.57 is the albumen height correction factor; and 0.37 is the egg weight correction factor.

The effects of the treatments on the variables were verified by analysis of variance. The effects of the storage temperatures were compared by the F-test, at 5% probability, while the effects of the storage time were estimated by fitting polynomial and linear regression equations.

All the statistical analyses were carried out with the SISVAR computational package (2000).

RESULTS AND DISCUSSION

The storage conditions significantly influenced ($P<0.05$) the egg weight and albumen quality characteristics. The eggs kept at ambient temperature had lower weight and worse albumen quality than those stored under refrigeration (Table 1).

The egg weight was negatively affected during the storage period, presenting a decreasing quadratic effect for those stored at ambient temperature (minimum point at 25.25 days) and a decreasing linear effect for those stored under refrigeration (Figure 1).

The results obtained for egg weight were similar to those reported by Nowaczewiski et al. (2010), who found the lowest egg weights after 5 and 8 days of storage in relation to the weight at laying. Dada et al. (2018) also observed a reduction of the weight of quail eggs stored under ambient conditions.

The interaction between storage time and temperature was significant ($P<0.05$) for albumen weight, which during the storage period diminished progressively

Table 1 - Egg weight (g), albumen height (mm), Haugh units, weight (g) and pH of quail eggs stored at ambient and refrigerated temperature

Characteristics	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
egg weight	Ambient[1]	10.12	9.54	9.22	8.80	8.97	9.13	9.30 A
	Refrigerated[2]	10.12	9.86	9.95	9.74	9.78	9.66	9.85 B
	Mean[3]	10.12	9.70	9.59	9.27	9.37	9.39	
	[1] $Y = 10.14 – 0.101X + 0.002X^2$; $R^2 = 97.64\%$; [2] $Y = 10.04 – 0.01X$; $R^2 = 78.84\%$; [3] $Y = 10.11 – 0.06X + 0.001X^2$; $R^2 = 95.77\%$ CV = 2.75%							
albumen height	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
	Ambient[1]	**3.96**	2.99	2.77	2.92	2.63	2.79	3.01A
	Refrigerated[2]	3.96	4.39	4.24	4.60	4.19	4.52	4.32B
	Mean[3]	3.96	3.69	3.50	3.76	3.41	3.65	
	[1] $Y = 3.81-0.096X + 0.002X^2$; $R^2 = 86.10\%$; [2] $Y = 4.13 + 0.01X$; $R^2 = 34\%$; [3] $Y = 3.92 – 0.032X + 0.0007X^2$; $R^2 = 57.02\%$ CV = 5.84%							
Haugh Units	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
	Ambient[1]	87.62	82.20	81.09	82.52	80.40	81.29	82.52A
	Refrigerated[2]	87.62	90.26	89.31	91.48	89.23	91.11	89.84B
	Mean[3]	87.62	86.23	85.20	87.00	84.82	86.20	
	[1] $Y = 86.70 – 0.49X + 0.01X^2$; $R^2 = 79.42\%$; [2] $Y = 88.11 + 0.18X – 0.0033X^2$; $R^2 = 48.49\%$; [3] $Y = 87.41 – 0.16X + 0.003X^2$; $R^2 = 41.62\%$ CV = 1.46%							
albumen weight	Storage Conditions							
		0	7	14	21	28	35	Mean[4]
	Ambient[1]	6.04	5.03	4.81	4.42	4.44	4.55	4.88A
	Refrigerated[2]	6.04	5.54	5.42	5.49	5.04	5.05	5.43B
	Mean[3]	6.04	5.29	5.11	4.96	4.74	4.80	
	[1] $Y = 5.96 - 0.12X + 0.002X^2$; $R^2 = 97.15\%$; [2] $Y = 5.89 – 0.026X$; $R^2 = 84.92\%$; [3] $Y = 5.96 – 0.082X + 0.0014X^2$; $R^2 = 96.01\%$ CV = 3.80%							
albumen pH	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
	Ambient[1]	9.33	9.35	9.37	9.25	9.49	9.42	9.37A
	Refrigerated[2]	9.33	8.85	8.89	8.75	9.12	9.00	8.99B
	Mean[3]	9.33	9.10	9.13	9.00	9.31	9.21	
	[1] $Y = 9.34 – 0.0024X + 0.00015X^2$; $R^2 = 30.10\%$; [2] $Y = 9.25 – 0.044X + 0.0011X^2$; $R^2 = 58.97\%$; [3] $Y = 9.30 – 0.023X + 0.0006X^2$; $R^2 = 47.21\%$ CV= 1.28%							

[4] Means followed by different letters in the column differ by the F-test at 5% significance.

according to a quadratic regression equation for those kept at ambient temperature and linearly for those stored under refrigeration (Figure 2). In the early days of

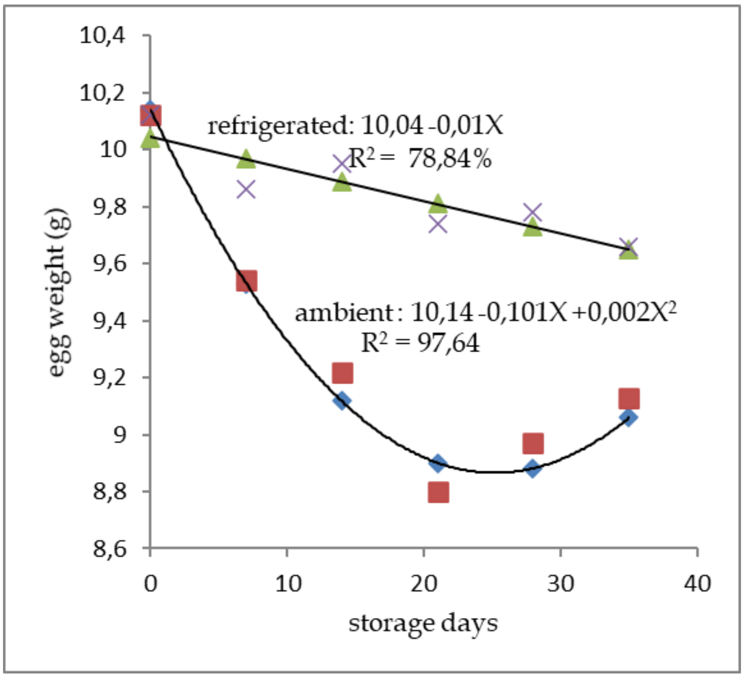

Figure 1 - Weight of quail eggs stored under ambient and refrigerated conditions.

storage, the reduction was more pronounced for the eggs kept at ambient temperature, certainly due to the exposure to higher temperature. The reduction of the albumen weight consequently influenced the egg weight, since albumen weight is the main component of egg weight.

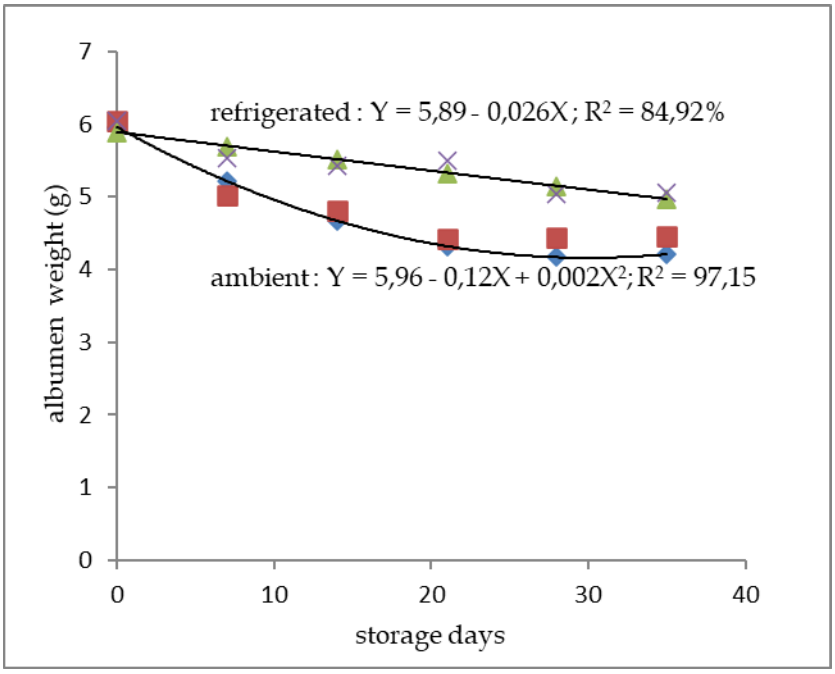

Figure 2 - Albumen weight of quail eggs stored under ambient and refrigerated conditions.

The reduction of albumen weight suggests the occurrence of water loss through the shell pores. According to Haugh (1937, cited by Dudusola, 2009), during storage eggs lose water, carbon gas, ammonia, nitrogen and sulfuric gas.

The storage period and temperature significantly influenced ($P<0.05$) the albumen height and HU, with the eggs kept at ambient temperature presenting lower average values than those stored under refrigeration.

The storage period had a decreasing quadratic effect on the albumen height and HU of the eggs stored under ambient conditions (the minimum point for albumen height was 24 days and for HU was 24.5 days). For the eggs kept under refrigeration, the effect was linear and increasing for albumen height and quadratic and increasing for HU (maximum point = 27.27 days) (Figures 3 and 4).

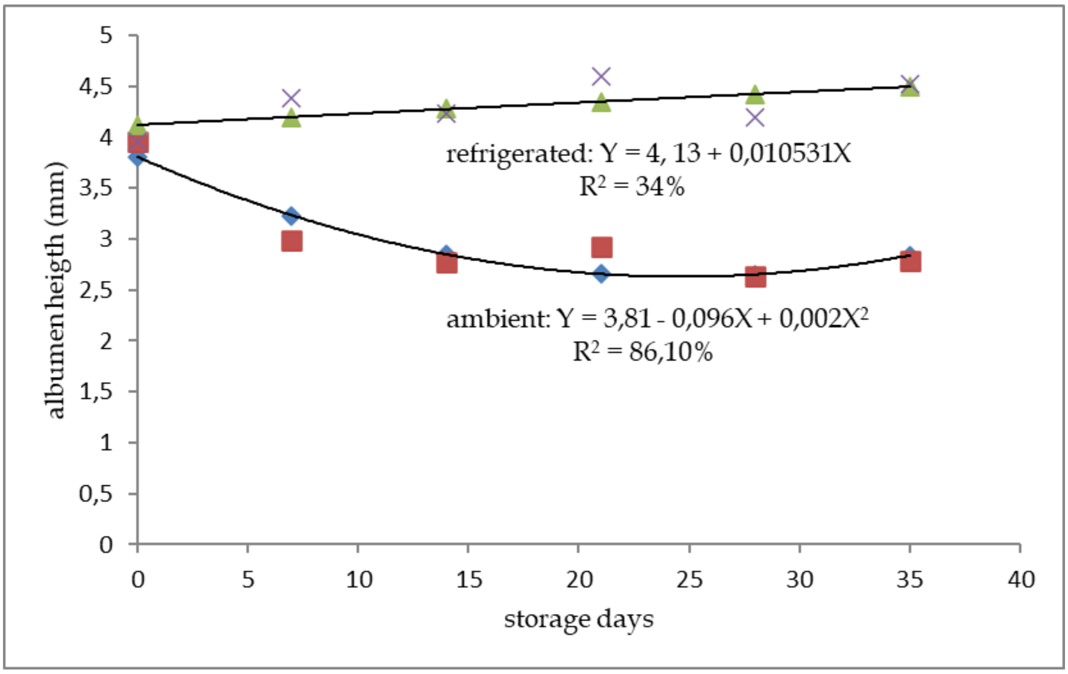

Figure 3 - Albumen height of quail eggs stored under ambient and refrigerated conditions.

According to Rocha et al. (2013), the albumen undergoes hydrolysis of amino acids, promoting destruction of the protein structure, compromising the vitelline membrane, reducing the viscosity and hence the albumen height.

The interaction between storage temperature and time was significant for albumen height and HU. The eggs kept under refrigeration presented small variations in the average values of albumen height and HU, while for those stored under ambient conditions the reductions of these parameters were greater, mainly in the first seven days, when the percentage reductions were 24.5% and 6.19% for albumen height and HU, respectively.

The results for albumen height of the eggs kept under refrigeration were

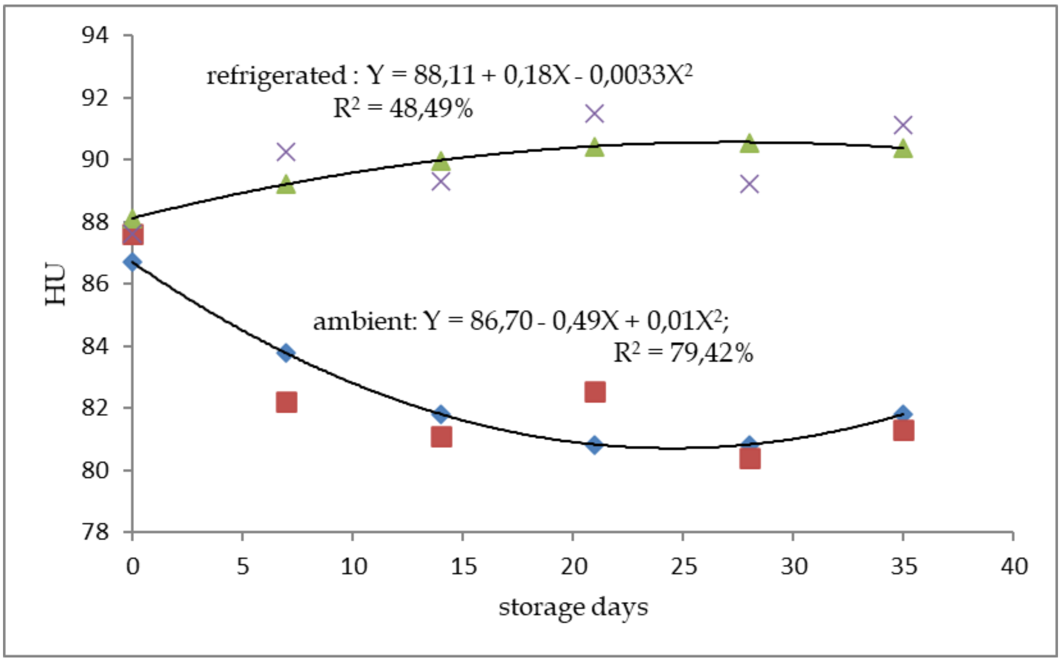

Figure 4 - HU of quail eggs stored under ambient and refrigerated conditions.

different than those reported by AL-Hajo et al. (2012), who observed that the internal quality of quail eggs, represented by albumen height, deteriorated with storage time from 10 to 30 days, even when refrigerated. They obtained mean albumen heights of 5.52, 3.93 and 3.34 mm for fresh eggs and those stored under refrigeration for 20 and 30 days, respectively.

The HU values of the eggs stored under refrigeration were different than those reported by Adamski et al. (2017), who obtained HU values of 91.4 after one week of storage and 87.2 after seven weeks for eggs kept at 4 ^{0}C. On the other hand, for the eggs maintained at ambient temperature, the HU results were similar to those of Akpinar et al. (2015), who reported decreased HU values of quail eggs stored at ambient temperature.

Nowaczewski et al. (2010) observed lower HU values after three storage periods (3, 5 and 8 days) at temperature of 19 °C and relative humidity of 50-55% compared to freshly laid eggs.

According to Nepomuceno et al. (2014), the HU value of eggs stored at 27.8±1.9 °C for 15 days after packaging was lower than that of eggs stored for 5 days.

The eggs maintained at ambient temperature presented more alkaline pH of the albumen (mean of 9.37) in comparison with the eggs kept refrigerated (8.99). This result is similar to that reported by Doğan et al. (2018), who found an increase of the albumen pH of eggs stored at 25 °C in relation to those kept at 4 °C.

The storage period had a decreasing quadratic effect on the albumen pH (Figure 5) of quail eggs stored under ambient and refrigerated conditions (minimum points of 8 and 20 days for the ambient and refrigerated temperature, respectively), although the coefficient of determination (R^2) was considered low (R^2 = 30.10%) for the eggs kept under ambient conditions.

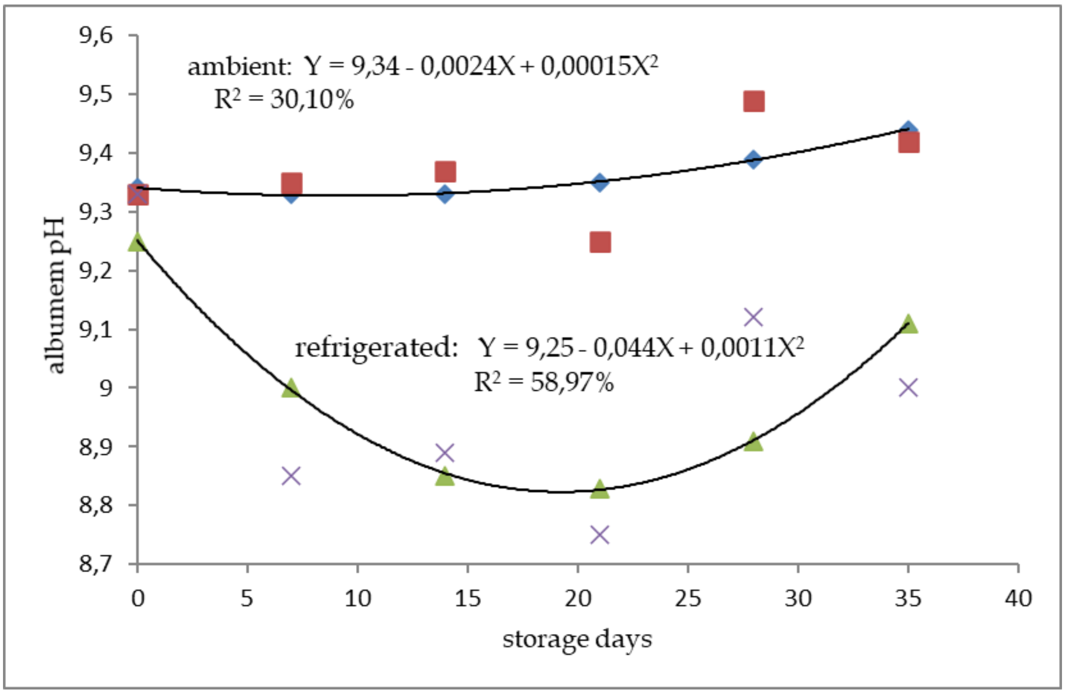

Figure 5 – Albumen pH of quail eggs stored under ambient and refrigerated conditions.

The albumen pH at the start of storage in this study was 9.33, higher than the values reported by Akpinar et al. (2015), of 8.28 and 8.90, and Dada et al.(2018) and Doğan et al. (2018), who found respective pH values of 7.28 and 8.78.

The albumen pH values of the eggs kept under refrigeration increased during storage, except after 21 days, when the average was lower than on the other days. Furthermore, during the entire storage period, the eggs kept at ambient temperature had lower albumin pH values than those kept under refrigeration. This suggests greater loss of CO_2 to the environment. According to Santos et al. (2016), the increase of albumen pH values during storage is related to the loss of carbon dioxide to the environment, a process that is accelerated by higher temperature. H_2CO_3, one of the components of the albumen buffer system, dissociates forming water (H_2O) and carbon dioxide (CO_2), after which the CO_2 is released to the environment, causing the albumen pH to increase.

Mendonça et al. (2013) reported that as the storage time without refrigeration of quail eggs increased, the albumen pH declined, even after treatment of the eggshell with a solution of propolis or mineral oil. However, Doğan et al. (2018) measured significant increases of the albumen pH of quail eggs with increased storage time and temperature.

For the yolk quality characteristics, the storage conditions had significant effects ($P<0.05$) on height, diameter, index and pH. The eggs kept under ambient conditions presented lower mean values of yolk height and index and higher values of diameter and pH in comparison with the eggs stored under refrigeration (Table 2).

The storage time had a rising quadratic effect (maximum point = 33.96 days) for yolk weight of the eggs stored in ambient conditions and a rising linear effect on the eggs kept under refrigeration (Figure 6).

During the storage period, the yolk weight of the eggs stored under both conditions increased. This result can be attributed to the passage of water from the albumen to the yolk. According to Mateos and Beorlegui (1991), cited by Mendonça et al. (2013), the increase of yolk weight during storage is due to physical and chemical reactions that lead to degradation of the protein structure of the thick albumen, with the water linked to large protein molecules passing to the yolk by osmosis, increasing its weight.

Our results for yolk weight differ from those reported by Nowaczewski et al. (2010), who did not observe any effect of storage time on the yolk weight of quail eggs.

According to Mendonça et al. (2013), the yolk weight presented a linear increase with the passage of time of eggs kept under refrigeration, irrespective of the shell surface treatment with mineral oil or a propolis solution.

The storage period had a decreasing quadratic effect on the yolk height of the eggs stored under ambient conditions (minimum point = 31.25 days) and a rising quadratic effect on the eggs kept under refrigeration (maximum point = 22.92 days) (Figure 7).

The storage time had a rising quadratic effect on the yolk diameter (maximum point = 38.29 days) and a decreasing effect on the yolk index (minimum point = 29.69 days) for the eggs stored under ambient conditions. However, for the yolk index of the eggs maintained under refrigeration, the storage time had a rising quadratic effect (maximum point = 22.83 days). No regression line could be fitted to the data on yolk diameter in function of storage time of the eggs kept under refrigeration (Figures 8 and 9).

Table 2. Yolk weight (g), height (mm), diameter (mm), index (%) and pH of quail eggs stored under ambient and refrigerated conditions.

Characteristics	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean
Yolk weight	Ambient [1]	3.2	3.57	3.47	3.45	3.59	3.61	3.48
	Refrigerated[2]	3.2	3.36	3.53	3.35	3.77	3.66	3.48
	Mean[3]	3.2	3.46	3.5	3.4	3.68	3.64	
	[1] $Y=3.29 + 0.018X - 0.000265X^2$; $R^2 = 60.05\%$; [2] $Y = 3.24 + 0.013X$; $R^2 = 70.70\%$; [3] $Y = 3.25 + 0.018X - 0.000195X^2$; $R^2 = 73.59\%$ CV = 5.70%							
	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
Yolk height	Ambient [1]	**9.72**	7.97	6.47	6.53	5.95	5.66	7.05 A
	Refrigerated[2]	9.72	10.33	10.83	11.02	10.81	10.67	10.56 B
	Mean[3]	9.72	9.15	8.64	8.77	8.38	8.16	
	[1] $Y = 9.58 - 0.25X + 0.00400X^2$; $R^2 = 96.50\%$; [2] $Y = 9.72 + 0.11X - 0.0024X^2$; $R^2 = 98.26\%$; [3] $Y = 9.65 - 0.069X + 0.000812X^2$; $R^2 = 93.80\%$ CV = 3.82%							
	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
Yolk diameter	Ambient [1]	23.64	27.22	28.79	30.07	31.55	32.12	28.90 A
	Refrigerated	23.64	23.89	23.69	23.43	23.82	23.71	23.69 B
	Mean[2]	23.64	25.55	26.24	26.75	27.69	27.91	
	[1] $Y = 23.93 + 0.43X - 0.005615X^2$; $R^2 = 98.88\%$; [2] $Y = 23.83 + 0.21X - 0.002708X^2$; $R^2 = 97.70\%$ CV = 2.18%							
	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
Yolk index	Ambient [1]	41.13	29.30	22.47	21.71	18.90	17.62	25.19 A
	Refrigerated[2]	41.13	43.24	45.70	47.06	45.38	45.03	44.59 B
	Mean[3]	41.13	36.27	34.08	34.38	32.14	31.33	
	[1] $Y = 39.97 - 1.49X + 0.025095X^2$; $R^2 = 96.99\%$; [2] $Y = 40.92 + 0.48X - 0.010509X^2$; $R^2 = 93.58\%$; [3] $Y = 40.44 - 0.50X + 0.007293X^2$; $R^2 = 93.70\%$ CV= 4.48%							
	Storage Conditions	Storage Period (days)						
		0	7	14	21	28	35	Mean[4]
Yolk pH	Ambient [1]	6.41	6.58	6.86	7.17	7.07	7.29	6.90 A
	Refrigerated[2]	6.41	6.24	6.52	6.91	6.72	6.91	6.62 B
	Mean[3]	6.41	6.41	6.69	7.04	6.90	7.1	
	[1] $Y = 6.38 + 0.04X - 0.000468X^2$; $R^2 = 94.66\%$; [2] $Y = 6.31 + 0.018X$; $R^2 = 70.79\%$; [3] $Y = 6.34 + 0.03X - 0.00025X^2$; $R^2 = 86.57\%$ CV = 1.67%							

[4] Means followed by different letters in the column differ by the F-test at 5% significance.

For the eggs kept under refrigeration, the yolk height decreased and the diameter increased with longer storage time, resulting in a reduction of the yolk index, which is the ratio of the yolk height and diameter. This behavior was observed from the start of storage, and on the seventh day there was a substantial change in the average values of these characteristics.

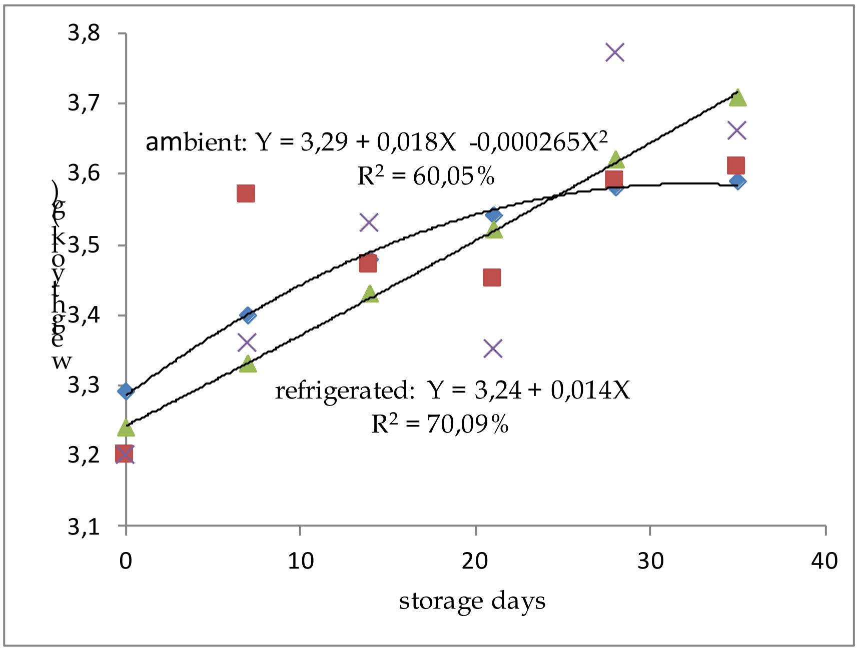

Figure 6 – Yolk weight of quail eggs stored under ambient and refrigerated conditions.

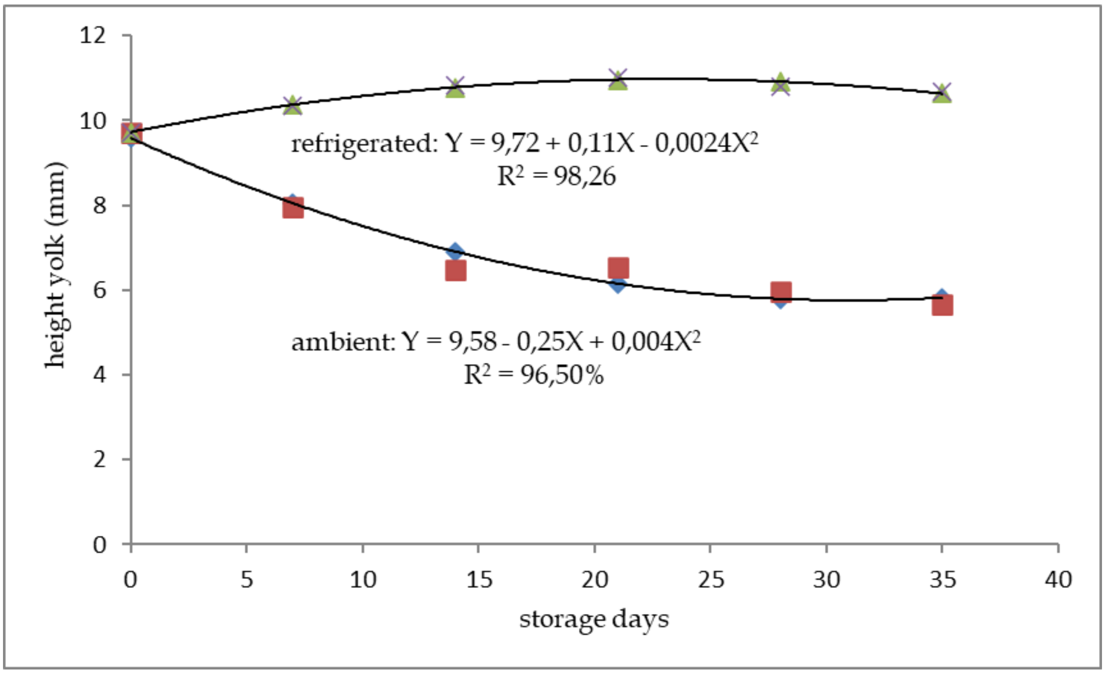

Figure 7 – Yolk height of quail eggs stored under ambient and refrigerated conditions.

According to Adamski et al. (2017), the vitelline membrane is an important component of the egg structure, by giving shape to the yolk and maintaining the diffusive equilibrium between the albumen and yolk. During long storage periods, the water in the albumen diffuses through the vitelline membrane to the yolk, increasing its volume.

The main alteration of the yolk index during storage is related to the loss of viscosity of the albumen and migration of water from the albumen to the yolk. The

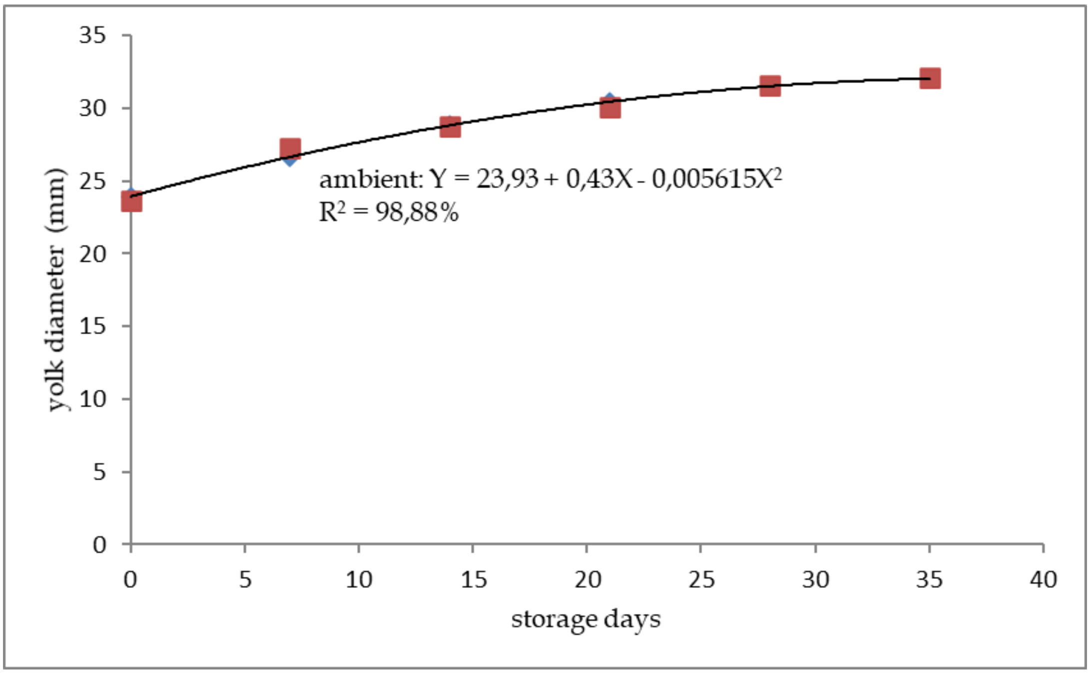

Figure 8 – Yolk diameter of quail eggs stored under ambient and refrigerated conditions.

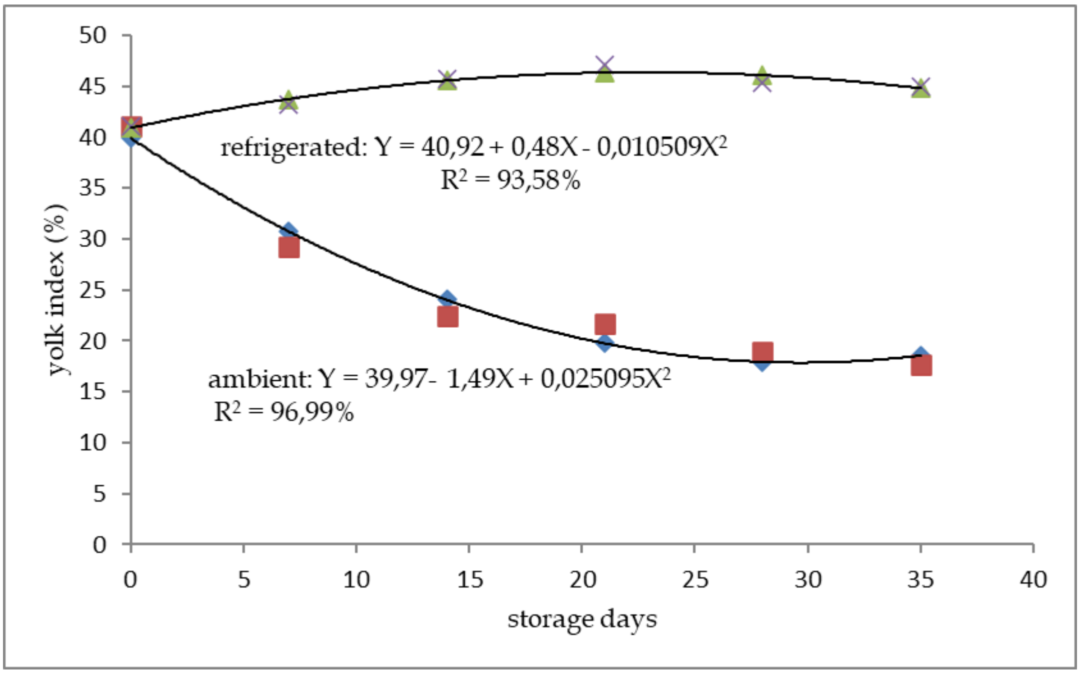

Figure 9 – Yolk index of quail eggs stored under ambient and refrigerated conditions.

added water in the yolk causes expansion and weakening of the vitelline membrane, allowing the yolk to flatten, resulting in increased width and reduced yolk index.

According to Nowaczewski et al. (2010), quail eggs after storage for 3, 5 and 8 days at temperature of 19 ^{0}C and relative humidity of 50-55% presented significantly lower yolk index values in comparison with those on day 0, with respective declines of 3.02, 4.23 and 7.39%.

Akpinar et al. (2015) reported that the yolk index of quail eggs decreased significantly with increased storage time at 25 °C. The values decreased from 49.12% to 35.12, 32.44, 29.99 and 27.43% for 1, 2, 3, 4 and 5 storage days, respectively.

The storage period had a rising quadratic effect on the yolk pH of the eggs kept under ambient conditions (maximum point = 42.73 days). On the other hand, for the eggs kept under refrigeration, the storage time had a linear effect on yolk pH (Figure 10).

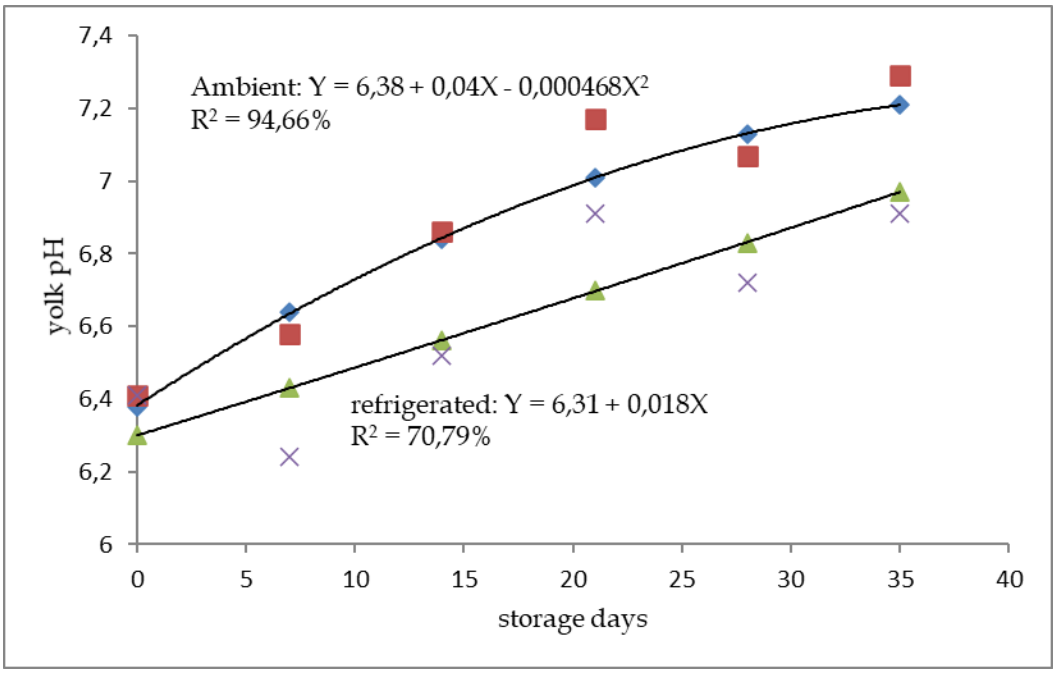

Figure 10 – Yolk pH of quail eggs stored under ambient and refrigerated conditions.

The yolk pH increased with advancing storage time under both storage conditions, but the eggs maintained at ambient temperature had higher yolk pH values than those stored under refrigeration. This result can be attributed to the exchange of alkaline ions in the albumen and H^+ ions present in the yolk, resulting in higher yolk pH, which can induce denaturing of proteins and increase the consistency of the yolk. Nepomuceno et al. (2014) also found that longer storage periods increased the yolk pH due to the greater permeability of the yolk membrane to ions.

According to Mendonça et al. (2013), the yolk pH increased linearly with storage time of eggs that did not receive treatment in comparison with those treated with mineral oil, and in quadratic form for eggs treated with propolis, with the lowest pH value being reached after storage for five days.

CONCLUSION

The storage of quail eggs under refrigeration preserved their quality for a period of 35 days. In contrast, for those stored under ambient temperature (varying from 14.08 to 38.7 ^{0}C), the egg quality parameters were negatively affected starting on the seventh day of storage.

REFERENCES

ADAMSKI, M.; KUŹNIACKA, J.; KOWALSKA, E.; KUCHARSKA-GACA, J. ; BANASZAK, M.; BIEGNIEWSKA, M. Effect of storage time on the quality of Japanese quail eggs (coturnix coturnix japonica). **Polish Journal of Natural Sciences**, v. 32, p. 27–37, 2017.

AKPINAR, G.C.; CANOGULLARI, S.; BAYLAN, M.; ALASAHAN, S.; AYGUN, A. The use of propolis extract for the storage of quail eggs. **Journal of Applied Poultry Research**, v.24, p.427–435, 2015. https://dx.doi.org/10.3382/japr/pfv043.

AL-HAJO, N.N.A.; ZANGANA, B.S.R.; AL-JANABI, L.A.F.; AL-KHALANI, F.M.H. Effect of coating materials (gelatin) and storage time on internal quality of chicken and quail eggs under refrigerated storage. **Egypt. Poult. Sci.,** v. 32, p.107-115, 2012.

DADA, T.; RAJI, A.; AKINOSO, R.; ARUNA, T. Comparative evaluation of some properties of chicken and Japanese quail eggs subjected to different storage methods. **Poultry Science Journal**, v. 6, p. 155 - 164, 2018. doi: 10.22069/psj.2018.14403.1308

DOĞAN, S. C.; BAYLAN, M.; YAMAN, S.; BULANCAK, A. Effects of dietary licorice root (Glycyrrhiza glabra) supplementation, storage time and temperature on quality of quail eggs. **Progress in Nutrition.** Vol. 20, p. 665-671, 2018. DOI: 10.23751/pn.v20i4.7854.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. **Pesquisa Pecuária Municipal**, 2017.

LANA, G. R. Q. **Avicultura**. Campinas, São Paulo, 2000. 268p.

MENDONÇA, M. O.; REIS, R.S.; BARRETO, S. L.T.; MUNIZ, J. C. L.; VIANA, G. S.; MENCALHA, R.;FERREIRA, R. C.; RIBEIRO, C. L. N. Qualidade de ovos de codorna submetidos ou não a tratamento superficial da casca armazenados em diferentes ambientes. **Revista Brasileira de Saúde e Produção Animal,** v.14, p.195-208, 2013. https://doi.org/10.1590/S1519-99402013000100019.

MORENG, R.E.; AVENS, J.S. **Ciência e produção de aves**. São Paulo: 1990.

NEMATI ,Z.; AHMADIAN, H.; BESHARATI, M.; LESSON, S.; ALIREZALU, K.; DOMÍNGUEZ, R.; LORENZO, J. M. Assessment of Dietary Selenium and Vitamin E on Laying Performance and Quality Parameters of Fresh and Stored Eggs in Japanese Quails. **Foods.** v. 9, p. 1324, 2020. doi:10.3390/foods9091324.

NEPOMUCENO, R.C.; WATANABE, P.H.; FREITAS, E.R.; CRUZ, C.E.B.; PEIXOTO, M.S.M.; SOUSA, M.L. Quality of quail eggs at different times of storage. **Ciência Animal** Brasileira, v.15, p. 409-413, 2014. https://doi.org/10.1590/1809-6891v15i424107

NOWACZEWSKI, S.; WITKIEWICZ, K.; KONTECKA, H.; KRYSTIANIAK, S.; ROSIŃSKI; A. Eggs weight of Japanese quail vs. eggs quality after storage time and hatchability results. **Archiv Tierzucht**, v. 53, p. 720-730, 2010.

PANDA, B.; SINGH, R. P. Developments in processing quail meat and eggs. **Worlds Poultry Science Journal**, v. 46, p. 220-234, 1990.

ROCHA, J.S.R.; BARBOSA, V.M.; LARA, L.J.C.; BAIÃO, N.C.; CANÇADO, S.V.; LANA, A.M.Q.; POMPEU, M.A.; VASCONCELOS, R.J.C.; MACHADO, A.L.C.; MIRANDA, D.J.A.; FERNANDES, M.N.S.; MENDES, P.M.M. Efeito do armazenamento e da cantaxantina dietética sobre a qualidade do ovo fértil e o desenvolvimento embrionário. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.65, p. 792-800, 2013. https://doi.org/10.1590/S0102-09352013000300027.

SANTOS, J.S.; MACIEL, L.G; SEIXA,V.N.C.; ARAÚJO, J.A. Parâmetros avaliativos da qualidade física de ovos de codornas (Coturnix coturnix japônica) em função das características de armazenamento. **Revista Desafios**, v. 03, p.54-67, 2016. http://dx.doi.org/10.20873/uft.2359-3652.

UNIVERSIDADE FEDERAL DE LAVRAS – UFLA. **Sistema para análise de variância para dados balanceados – SISVAR.** Lavras, MG, 2000.