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Temperature and shelving period effect on albumin height and color of supermarket eggs sold in northwest Mexico

Efecto de la temperatura y tiempo de almacén en la altura de la albúmina y el color del huevo de supermercado en el noroeste de México

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ABSTRACT

Changes in albumin height and yolk color of supermarket eggs were determined by a regression model with dummy variables after periods of 1, 3 and 6 days. A first group included eggs stored above 25 °C, while the second included eggs stored below 25 °C. It was found that although on day one, eggs in both group were classified in the highest quality category, after six days a reduction in albumin height placed both groups in the second quality classification. However, it was found that percentage loss for group below 25 °C was smaller than reduction in group above 25 °C. Percentage of change in yolk color measured by L* a* and b* was smaller for the group above 25 °C. Results indicate that when temperature in a supermarket reaches 25 °C or more, eggs should not be stored for more than six days.

RESUMEN

Mediante regresión lineal con variables ficticias, se determinaron los cambios en altura de albúmina y color de la yema en huevos de supermercado en anaquel durante 1, 3 y 6 días. Los huevos fueron congregados en dos categorías: un grupo con temperatura ambiental mayor a 25 °C y otro con temperatura inferior a 25 °C. Se encontró que ambos grupos iniciaban su vida de anaquel con la clasificación cualitativa más alta, pero que al sexto día disminuía a la segunda categoría. Sin embargo, el grupo almacenado por debajo de 25 °C presentaba un menor efecto sobre la altura de la albúmina. Los cambios porcentuales en el color de yema medidos con L* a* y b* fueron inferiores para el grupo por abajo de 25 °C. Los resultados indican que cuando la temperatura alcanza o rebasa los 25 °C, los huevos no deben permanecer en el anaquel más de una semana.

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Egg; albumin height; color; temperature, storage.

Palabras clave:
Huevo; altura de albúmina; color; temperatura; almacenamiento.

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INTRODUCTION

Egg quality is given by a group of characteristics that include size, shell thickness and color, albumin thickness and yolk color. But when consumers are asked about what is the most important quality trait, answers are: freshness followed by yolk color in order of importance (Arias, Fernández & Nys, 1998).

As soon as the egg is laid, physical and mechanical changes occur that affect its quality, one of them is weakening of vitelline membrane that separate yolk and albumin. Consequences of these changes may be assessed by measuring height of albumin using Haugh units (Berardinelli, Ragni, Giunchi, Gradari & Guarnieri, 2008).

Haugh unit is the most common parameter to measure albumin quality and it relates egg´s weight to albumin height, whereas high quality eggs have a higher greater Haugh units score (Alleoni & Antunes, 2001). Nevertheless, correction for egg weight use in the Haugh unit formula adds a bias to the calculation and it is not considered reliable. Because of this situation, albumin height measurement is viewed as a recommended alternative to measure albumin quality due to the fact that it can be measured anywhere with basic equipment (Silversides & Budgell, 2004).

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Research suggest that changes in albumin quality over time at room temperature storage are equally well described by albumin height and the Haugh unit score. Therefore, egg weight adjustment use in Haugh unit is unnecessary (Silversides & Villeneuve, 1994).

Ovomucin layer, responsible for the firmness of thick albumin, becomes weak when stored for a long period. Therefore, albumin spreads over a wide range of area in an abnormal manner when an egg is broken, causing an increase in albumin length and width. As a result, albumin height decreases (Alade, Usman & Muhammed, 2013).

Albumin height of eggs reaches a maximum when an egg is laid and decreases when storage time increases (Jin, Lee, Lee & Han, 2011). However, quality can be maintained if immediately after collection an egg is held at temperatures between 0 °C and 4 °C (Barbosa, Sakomura, Mendonça, Freitas & Fernandes, 2008). It has been reported that eggs quality suffers no significant changes even after 20 days in storage if they are refrigerated (Estrada, Galeano, Herrera & Restrepo, 2010). Other factors that are considered to affect albumin quality are: strain of bird, genetic selection and also hen age, as albumin quality declines with bird age. It has been reported that infectious bronchitis affects albumin quality; on the contrary, albumin quality is not greatly influenced by bird nutrition (Roberts, 2004).

An important factor that determines acceptability of an egg for the consumer is intensity and uniformity color of yolk (Samli, Agma & Senkoylu, 2005). Even so, it is important to consider that color preferences by consumers differ around the world. A study done in Turkey found that dark color yolk is preferred but also that color is not an important quality trait (Karadas, Grammenidis, Surai, Acamovic & Sparks, 2006). To accurately determine yolk color in a color sphere, it is recommended to use L* (lightness) a* (redness) and b* (yellowness) measurements (Mizrak *et al.*, 2012).

In Mexico, eggs quality is determined by the NMX-FF-079-SCFI-2004 Federal norm. According to albumin height score, product is classified in four categories: Mexico extra (≥ 5.5 mm), Mexico I (4.2 mm – 5.4 mm), Mexico II (2.2 mm – 4.1 mm) and outside of classification (< 2.2 mm). In the case of yolk color, norm states that in all classification color should be between a 9 to 12 score in Roche colorimetric fan. In case of storage, norm only states that storage conditions should be cool and dry and that eggs package displays an expiration date (*Secretaría de Economía* [SS], 2004).

It has been reported that supermarket eggs have a higher internal quality (Leandro *et al.*, 2005) if they have a shorter display period and a more stable environment. Although if supermarkets do not provide this conditions, quality is compromised. Eggs sold in Mexican supermarkets are mostly displayed under room conditions and because the Mexican norm only recommends that eggs are stored under cool and dry conditions. It is common that eggs are not refrigerated to reduce effect of long time storage. Because of this consumers will buy low quality eggs without them knowing and the likelihood of this happening increase if room temperature of supermarket is high.

It is important to measure how quality of supermarket eggs decays along time, so retailers are better informed and they are able to offer eggs with the internal quality characteristics that consumers expect.

Therefore, objective of this work is to quantify the internal quality change that exhibit supermarket eggs that are shelved up to 6 days in storerooms with high temperature change so that more information is made available to the supplier and consumer of this good.

MATERIALS AND METHODS

The study was carried out between September and December in the city of Mexicali, located in northwest Mexico (latitude 32º 40', longitude 115º 28'). Climate is characterized as extremely arid with rainfall rarely exceeding 100 mm per year, and an average temperature of 34.7 °C (–5 °C in winter and 50 °C during the summer), and an altitude of 3 m (García, 1981). Eggs used in the study were obtained from a local farm that uses a 72 week production system and were produced by hens from the hy-line strain. After collection eggs were stored at 4 °C to 8 °C for less than 12 h before being distributed to four local supermarkets. Eggs were tracked from farm to supermarket using lot number. To classify eggs based on measurements of albumin height and yolk color Mexican egg quality norm NMX-FF-079-SCFI-2004 was employed.

Two groups of eggs were collected from supermarkets storerooms. The first group included eggs from the same lot stored at temperatures above 25 °C with a temperature range between 25.7 °C and 30 °C, while the second included eggs that were stored below 25 °C. In this case temperature span was between 18.5 °C to 20.8 °C, to assure in both groups an adequate number of eggs for subsequent samplings, 100 eggs were collected on the first day they were displayed and the lot number registered, so that samples two and three were part of the same lot. Second collection was done three days later and a sample of 57 eggs was obtained from the above 25 ºC group and 58 eggs from the below 25 ºC. The last sampling was done 6 days after the first, and in this case 57 eggs were collected from the first group and 56 from the second.

Immediately after collection, eggs were placed in a cooler, transported to a laboratory, and analyzed the same day. Albumin height and color values used in this study were the mean of three measurements obtained directly from each egg after it was placed on a chopping board. Height of the albumin was measured using an digital micrometer (Ames, model 03-0230Q, USA) (Juárez-Caratachea, Gutiérrez-Vázquez, Segura-Correa & Santos-Ricalde, 2010), and in the case of yolk color the measurement instrument was a Minolta CM-2002 spectrophotometer with a specular component, a D65 illuminant and a 10º observer (Minolta Camera Co., Ltd, Japan). Yolk color was expressed in the CIELAB dimensions of lightness (L*), redness (a*), and yellowness (b*).

To obtain the albumin height mean and measure yolk color of eggs on the day they were placed on shelves, as well as changes in albumin height and color that eggs in the two groups attained after spending 3 and 6 days on store shelves, the following linear regression model with dummy variables was used (Asteriou & Hall, 2007):

$$y_i = \beta_0 + \beta_1 D_{1i} + \beta_2 D_{2i} + u_i.$$

Where:

β_0: Intercept, which in this case is the main value of dependent variable (albumin height or color) obtained on the day anegg is placed on store shelves.

β_1: The changes in albumin height or color that eggs show 3 days after being placed on the store shelves.

D_1: Dummy variable that takes a value of 1 if the egg is from the group that has been on the store shelves for three days, or takes the value of 1 in any other case (0 and 6 days).

β_2: The changes in albumin height or color that eggs show 6 days after being placed on the store shelves.

D_2: Dummy variable that takes a value of 1 if an egg is from the group that has been on store shelves for six days, or takes value of 1 in any other case (0 and 3 days).

With the use of dummy variable in regression models, it is viable to quantify the effect that nominal independent variable (period on display) had on dependent variable (albumin height or color) (Gujarati & Porter, 2009). Although the number of days that eggs are displayed on showroom may be seen as a continuous variable, because no data between 0 and 3 days and between 3 and 6 days was recorded. It was possible to consider time spent on shelves as a qualitative variable that was given 1 as a value when the variable possessed the attribute (AH on day 0) and 0 otherwise (AH on days 3 and 6) (Asteriou & Hall, 2007). Statistical analysis was done using Megastat program, 2007 version.

RESULTS

Results of ordinary least square estimation of both groups of eggs indicate that after being placed on supermarket shelves, eggs show a statically significate reduction in albumin height (AH) ($p < 0.01$). However, this decline is even larger in the > 25 ºC group. After 6 days on shelves, eggs from this group reduced their quality 44.23%, while eggs in the < 25 ºC group lost only 32.2%. Table 1 shows that on day 1, eggs in the > 25 ºC group had a mean 8.32 mm AH, which according to the NMX-FF-079-SCFI-2004 norm places them in the highest quality category (Mexico extra). After 3 days, AH mean value dropped to 5.55 (8.3212 – 2.7712) which placed eggs in the upper limit of Mexico I category. On the other hand, after 6 days in shelves eggs had a 4.6317 mean (8.3212 – 3.6895), maintaining them in Mexico I category.

In the case of < 25 ºC group (table 2), AH mean on day 1 although lower than mean of > 25 ºC group, was still large enough to place eggs in Mexico extra category. After three days reduction of AH mean was 1.61 mm which placed it in 6.15 mm, this decline in AH did not affect eggs classification. After six days on shelves mean was 5.25 mm, with this value eggs are classified as Mexico I, although if calculations are done using results of upper limit of confidence interval, AH mean is 5.86 mm (7.9908 – 2.1297). So, that even after six days of being place in storeroom, eggs may maintain their Mexico extra classification.

Table 1.
Albumin height coefficients and confidence interval for the > 25 ºC group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	**Coefficients**		**95 % lower**	**95 % upper**
Intercept	8.3212**	0.1236	8.0776	8.5649
Three days	–2.7712**	0.2056	–3.1766	–2.3659
Six days	–3.6895**	0.2033	–4.0904	–3.2886

** p<0.01
Source: Author's own elaboration.

Table 2.
Albumin height coefficients and confidence interval for the < 25 ºC group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	Coefficients		95 % lower	95 % upper
Intercept	7.7620**	0.1161	7.5332	7.9908
Three days	–1.6137**	0.1916	–1.9914	–1.2361
Six days	–2.5094**	0.1926	–2.8891	–2.1297

** $p < 0.01$
Source: Author's own elaboration.

Table 3.
L* coefficients and confidence interval for the > 25 ºC group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	Coefficients		95 % lower	95 % upper
Intercept	51.568**	0.4002	51.0938	52.0423
Three days	1.236**	0.3958	0.4477	2.0258
Six days	1.793**	0.1926	1.0127	2.5732

** $p < 0.01$
Source: Author's own elaboration.

Table 4.
L* coefficients and confidence interval for the < 25 ºC group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	Coefficients		95 % lower	95 % upper
Intercept	45.3801**	0.3231	44.7432	46.0169
Three days	2.6543**	0.5332	1.6032	3.7053
Six days	3.2768**	0.5362	2.2199	4.3337

** $p < 0.01$
Source: Author's own elaboration.

Table 5.
a* coefficients and confidence interval for the > 25 ºC group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	Coefficients		95 % lower	95 % upper
Intercept	12.0908**	0.2072	11.6824	12.4993
Three days	–1.2476**	0.3447	–1.9271	–0.5681
Six days	1.1988**	0.3409	0.5268	1.8709

** $p < 0.01$
Source: Author's own elaboration.

Table 6.
a* coefficients and confidence interval for the < 25 ºC group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	Coefficients		95 % lower	95 % upper
Intercept	15.5185**	0.2480	15.0297	16.0073
Three days	–0.8782*	0.4093	–1.6849	–0.0714
Six days	–0.8471*	0.4115	–1.6583	–0.0359

** $p < 0.01$
Source: Author's own elaboration.

Table 7.
b* coefficients and confidence interval for the > 25 ºC group

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	Coefficients		95 % lower	95 % upper
Intercept	30.3786**	0.4082	29.5739	31.1833
Three days	15.5134**	0.6791	14.1746	16.8521
Six days	7.6238**	0.6716	6.2999	8.9477

** $p < 0.01$
Source: Author's own elaboration.

Two interesting findings were that in both groups, rate of decline of AH was smaller between 3 to 6 day periods than between 1 to 3 day period and that percentage loss in this period for < 25 ºC group was smaller (20.74%) than reduction in > 25 ºC group (33.30%). Similar reductions were observed for both groups in 3 – 6 days period. These results indicate that higher room temperature had a greater negative impact on AH.

In the case of L* it was found that yolk in > 25 ºC group showed a 2.38% increase in luminosity after 3 days in shelves (table 3). In < 25 ºC group change was 5.83% (table 4). In both cases after 6 days on shelves L* increased.

Considering that lower values of a* indicate that yolk contains less red pigment, results obtained in > 25 ºC group indicate that after 6 days yolk increases it redness placing a* mean at 13.3 (table 5), even though a small reduction was seen after eggs spent 3 days in shelves. In the case of < 25 ºC group, behavior of a* was different when compared to the other group. In this case values of a* declined, so that after 6 days mean was 0.8471 units lower (table 6).

Behavior of b* was different for both groups, after 6 days value of b* in > 25 ºC group showed a 7.62 unit increase (table 7), approaching b* to upper limit of color scale which is 60.

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Table 8.
b* coefficients and confidence interval for the < 25 °C group.

R = 0.804	R^2 = 0.646	SE	Confidence interval	
Variables	**Coefficients**		**95 % lower**	**95 % upper**
Intercept	42.8736**	0.5190	41.8505	43.8967
Three days	–2.6945**	0.8566	–4.3830	–1.0059
Six days	–3.3668**	0.8614	–5.0647	–1.6688

** $p < 0.01$
Source: Author's own elaboration.

In < 25 °C group, yellowness of yolk decreased (table 8) and although change was of only 3.36, result is viewed as interesting considering that in > 25 °C group behavior was opposite.

DISCUSSION

Values of AH found by this study are similar to the ones reported by a research done in Baghdad that examined locally produced eggs that were sold in retail stores, where AH mean was 7.3 mm (Al-Obaidi, Shahrazad, Al-Shadeedi & Al-Dalawi, 2011). This good score indicated that egg producers followed procedures that enable them to supply high quality eggs to retailers.

In general, results of this research are in agreement with findings of a study performed in Nigeria (Alade *et al.*, 2013) which showed that in temperatures between 30 °C and 40 °C, decline of AH accelerated as storage time increased. This is explained by the fact that changes in internal egg quality are attributed to dehydration by evaporation through pores in the shell and escape of carbon dioxide from albumin (Lumpkins, Batal & Dale, 2005).

On the other hand, a study done in Iraq showed AH results very similar to the ones obtained in the present study after 3 days on shelves and equal results in 6 day eggs (Ihsan, 2012). An explanation for this may be that rate of temperatures in both studies was similar (25 °C to 30 ° C).

Findings suggest that is difficult to maintain good egg quality over 6 days if room temperature where eggs are shelved is above 25 °C. Considering that previous research has found that physical quality factors of eggs during storage were still acceptable beyond recommended shelf life guidelines when eggs are refrigerated at 4 °C (Jones & Musgrove, 2005).

Albumin quality of an egg is not greatly influenced by production factors like nutrition, housing, environment and even heat stress (Williams, 1992). Therefore, considering results of this research an efficient way to influence albumin quality is by refrigerating the product when store room temperature is above 25 °C. As a result of this, the product offered will meet quality traits for which consumers are paying. Under high temperature conditions that eggs are sold by local supermarkets, a consumer that purchases a 6 day old egg may be acquiring a product that might not be recommended for human consumption.

Retailers should not underestimate consumer ability to evaluate freshness of eggs trough albumin acceptability. It has been reported that a group of panelists were able to tell difference between recently laid eggs and 7, 14 and 21 day old eggs stored at 18 °C and 32 °C (Karoui *et al.*, 2006).

In the case of yolk color, consumer's preferences vary geographically, however in most parts of the world they prefer deeply hued yolks (Beardsworth & Hernández, 2004). And golden to yellow colors are usually preferred (Baiao, Méndez, Mateos, García & Mateos, 1999).

The increase of L* after 6 days is in agreement with behavior previously reported by other researchers that found that it is during the first week of storage when luminosity increases the most, although it must be noted that the results were obtained using refrigerated eggs (Jones, 2007).

Regarding b*, < 25 °C group behave differently to what other researchers report, as it showed a decrease in value that results in yolk looking less yellow (Bhale *et al.*, 2003).

Although time of storage is a factor that affects egg yolk color as a result of water entering yolk causing dilution of pigment (Carranco-Jáuregui *et al.*, 2006). In this study changes in both groups after 3 and 6 days were small. This may be explained by studies that indicate that changes in yolk color are noticeable after 21 days of storage (Vieira-dos Santos *et al.*, 2009) and that after 3 days significant color differences may not be observed (Karadas *et al.*, 2006).

Consumers prefer products with high quality, fresh, safe and environmental friendly, although it is difficult to market products of increasing high quality at a low price (Ness & Gerhardy, 1994). In the present case retailers are in a position to offer good quality eggs by making small and low cost changes in their storage procedure. Based on findings of this study, which concurred with other results (Ihsan, 2012), it is recommended that when room temperature reaches 25 ºC or more, eggs should not be stored for more than six days before consumption. This recommendation becomes more relevant when eggs are also exposed to low humidity (Al-Obaidi *et al.*, 2011).

Good quality of an egg must not only be considered important because of consumer preferences, it is also a relevant characteristic because of health reasons, due to the fact that quality decline is generally accompanied by increased microbial growth. Rapid cooling of eggs is highly recommended as it is considered one of the most effective means of reducing illnesses caused by egg consumption (Caudill *et al.*, 2010).

After being laid, eggs may spend a large amount of time in store shelves, so more knowledge is needed regarding changes in properties that take place over time when eggs are on displayed for consumers. As a result, researchers (Karoui *et al.*, 2006) have suggested construction of models based on destructive and non-destructive techniques to determine age of commercial shell eggs in order to predict remaining shelf life of product.

CONCLUSIONS

Although Mexican norm does not require that retailers keep eggs under refrigeration. In areas like the one in which this study was conducted where temperatures can reach 45 ºC, it is important that store owners be aware that they play a vital role in assuring that eggs maintain expected quality by consumers. Consequently, when temperature in a supermarket reaches 25 ºC or more, eggs should not be stored for more than one week without refrigeration.

Based on findings of this study, if purchase is centered on expiration date and eggs were stored for six or more days above 25 ºC, a consumer may think that in regard to quality he or she is making the best purchase decision, when in fact, based on the product quality, disbursement is excessive.

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