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Research article

Egg quality during storage of eggs from hens fed diets with crude palm oil

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ABSTRACT

Objective. Evaluate the effect of crude palm oil (CPO) on quality traits of eggs stored various days at different temperatures. **Material and Methods.** A total of 240 hens, 28 weeks of age were fed diets with 30 g/kg of soybean oil (SO) or CPO. After 12 weeks, sample of eggs were stored during 0, 4, 8 and 12 days at 4, 12 and 24 °C. Egg quality traits were evaluated. **Results.** Egg and albumen from hens in CPO diet were heavier than those in SO ($p<0.05$). High storage temperature reduced egg, albumen and yolk weights, Haugh units (HU), albumen and yolk heights, pH and color ($p<0.05$), but increased albumen and yolk widths and albumen length ($p<0.05$). As storage time increased, egg weight, albumen weight and height, and yolk height, pH and colour were reduced ($p<0.05$). However, yolk weight and width, albumen width and length increased ($p<0.05$). Oil x storage time interaction ($p<0.05$) indicated that albumen height, HU and yellowness of yolk from hens in CPO diets were better at 12 days of storage than for hens fed SO. **Conclusions.** Hens in CPO diet had heavier eggs and albumen than those in SO diet. Egg quality traits decreased as temperature and days of storage increased, but, eggs from hens supplemented CPO had better quality in some traits at 12 days of storage.

Keywords: Egg deterioration, egg properties, *Elaeis* guineensis, layer chickens, storage conditions (*Sources: Agrovoc, CAB*).

RESUMEN

Objetivo. Evaluar el efecto del aceite crudo de palma (ACP) sobre la calidad del huevo almacenado por varios días a diferentes temperaturas. **Materiales y métodos.** Un total de 240 gallinas de 28 semanas se alimentaron con dietas con 30g/kg de aceite de soya (AS) o ACP. Después de 12 semanas, muestras de huevos se almacenaron durante 0, 4, 8 y 12 días a 4, 12 y 24°C. Las características de calidad del huevo fueron evaluadas. **Resultados.** El huevo y la albúmina de gallinas en la dieta con ACP fueron más pesados que aquellos en la dieta con AS ($p<0.05$). La alta temperatura de almacenamiento redujo el peso del huevo, albúmina y yema, unidades Haugh (UH), altura de la albúmina y la yema, pH y color ($p<0.05$), pero aumentó el ancho de la albúmina y la yema, y la longitud de la albúmina ($p<0.05$). A medida que aumentaba el tiempo de almacenamiento, el peso del huevo, el peso y la altura de la albúmina, y la altura de la yema, el pH y el color se redujeron ($p<0.05$). Sin embargo, el peso y el ancho de la yema, el ancho y la longitud de la albúmina aumentaron ($p<0.05$). La interacción aceite x tiempo de almacenamiento ($p<0.05$) indicó que la altura de la albúmina, UH y el color de la yema de las gallinas en la dieta de ACP fueron mejores a los 12 días de almacenamiento que las gallinas con AS. **Conclusiones.** Las gallinas en la dieta con ACP tuvieron huevos y albuminas más pesadas que las de las de la adieta con AS. La calidad del huevo disminuyó conforme el tiempo y temperatura de almacenamiento se incrementó, pero, los huevos de las gallinas suplementadas con ACP tuvieron mejor calidad en algunas características a los 12 días de almacenamiento.

Palabras clave: Condiciones de almacenamiento, deterioro del huevo, *Elaeis guineensis*, gallinas de postura, propiedades del huevo (*Fuente: Agrovoc, CAB*).

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INTRODUCTION

In tropical regions, the ambient temperature commonly reaches more than 30°C. Those temperatures affect negatively the quality of eggs during storage. Because of storage time and temperature, eggs lost weight, albumen reduces height and length, vitelline membrane becomes weak and yolk gets flattened (1,2).

Storage of eggs at 4°C reduced significantly the egg weight loss (3,4,5). However, in tropical areas, eggs are exposed to warm temperatures during handling, transportation and distribution of eggs. Physical and chemical characteristics of eggs like albumen and yolk pH increased and thickness of albumen and yolk index reduced when eggs were stored at 25°C (2). Many physicochemical processes happen in the eggs when stored. Among them, can be mentioned an increase in trypsin activity in the albumen, that increases the liquefaction of the thick albumen portion (6); and an increase in pH in both albumen and yolk due to the release of carbon dioxide (1,2). To avoid this oxidative process, antioxidants are added to the hen's diet. Natural antioxidants such as vitamin E or α-tocopherols have been studied, with good results (7,8).

Crude palm oil extracted from the fruits of the palm oil tree (*Elaeis guinensis*) consist mainly of unsaturated fatty acids (50%) and saturated fatty acids (50%) (9). Njoku and Nwazota (10) found that the inclusion of 50 g/kg palm oil increased egg production, egg weight, food intake and feed utilization. Furthermore, palm oil has a great content of vitamin E in form of α-tocopherols and tocotrienols that have shown reduction of oxidative process in the endothelial tissues (11,12,13,14). However, there is no information about the use of crude palm oil in hen diets and its effect on the quality of eggs during storage.

Therefore, the objective of the present study was to evaluate the effect of adding crude palm oil in diets of laying hens on egg quality traits of eggs stored various days at different temperatures.

MATERIAL AND METHODS

Animals and housing conditions. Two hundred and forty hens (Isa-Babcock B-300), 28 weeks of age that started production at 18 weeks, and reached peak of production at 28 weeks of age were used. The experimental period began after peak of production and lasted 12 weeks. The hens were randomly distributed in cages of 40 cm x 40 cm. Thirty cages with two hens by cage and twenty cages with three hens by cage in each treatment for a total of 50 cages (experimental unit) were used. There were 50 replicates by source of vegetable oil evaluated. The cages had individual feeders of 400 g capacity.

Experimental diets. A basal diet was designed according to the requirement for laying hens (15), with 30 g/kg of crude palm oil (CPO) or soybean oil (SO) depending of the treatment (Table 1). The basal diet was composed of sorghum and soybean meal. The birds had free access to feed and water throughout the experiment. The feeders were fill every day to kept *ad libitum* feeding condition. Average feed intake was calculated every week as difference of feed offered and refused, between birds in each cage. The average feed intake recorded during the experimental period were 100.8±7.8 and 101.2±8.2 g for SO and CPO diets respectively.

Table 1. Ingredients and chemical composition of the basal diets.

Ingredient	g/kg
Sorghum	549.0
Soybean meal	296.0
$CaCO_3$	99.0
Dicalcic phosphate	18.6
Soybean oil or Palm oil	30.0
NaCl	3.0
Vitamin and Mineral premix[1]	2.0
DL-Methionine	1.3
Coline chloride	0.5
Pigment	3.0
Total	1000
Calculated Analysis (%)	
Calcium	4.20
Available phosphorous	0.45
Methionine	0.40
Methionine + Cistine	0.71
Lysine	0.92
Crude protein	18.50
ME (Mcal/kg)	2.75

[1]Vitamin and mineral premix: Mn, 65 mg; I, 1 mg; Fe, 55 mg, Cu, 6 mg; Zn, 55 mg; Se, 0.3 mg; vitamin A, 8000 UI; vitamin D, 2500 UI; vitamin E, 8 UI; vitamin K, 2 mg; vitamin B_{12}, 0.002 mg; Riboflavin, 5.5 mg; Calcium pantothenate 13 mg; Niacine, 36 mg; Choline chloride, 500 mg; Folic acid, 0.5 mg; Thiamine, 1 mg; Pyridoxine, 2.2 mg; Biotin, 0.05 mg.

Storage time and temperature. After twelve weeks of feeding, one egg of each cage was randomly collected, during four consecutive days. The collected eggs were assigned to four storage times (0, 4, 8 and 12 days) and three storage temperatures (4, 12 and 24°C). Therefore, there were 12 treatment combinations of storage time and storage temperature. The eggs at 4°C were stored in a refrigerator. The eggs at 12 and 24°C were stored in rooms with air conditioners calibrated to the corresponded experimental temperature. After the storage time assigned, eggs were weighed (scale of 0.1 g, Ohaus CS 200), broken carefully and the content (yolk and albumen) was smoothly deposited on a flat plate. The length and width of albumen and yolk were measured with a vernier

(Vernier calibrator 150 mm, Surtek company) and the height with a micrometric screw (Digital micrometer 25 mm, Syntek). Then, the yolk and the albumen of each egg were weighed. Yolk colour was evaluated visually with a Roche yolk colour fan with 15 colour gradation (DSM company, animal nutrition and health). The pH in yolk was measured with a portal pH meter (Oakton, ecotester).

Haugh Unit (HU) was calculated using the formula of Eke et al (1):

$$HU = 100 \log (AH + 7.57 - 1.7W^{0.37})$$

Where:
HU = Haugh unit
AH = Albumen height (mm)
W = Egg weight (g)

Statistical analysis. The effect of oil source, storage time and temperature on egg traits was evaluated using a split plot design; where source of oil was the main plot, and temperature and time of egg storage levels combination was the sub-plots. Source of oil effect was tested using as experimental error, replicates within oil sources mean squares. The effect of temperature, time of storage, source of oil x temperature, source of oil x storage time and temperature x time was tested with the residual mean squares. Temperature and time mean comparison where made using Tukey tests. All statistical analysis was carried out using the GLM procedure of SAS (16).

RESULTS

Egg quality trait and Haugh units. As it is shown in table 2, eggs and albumen of laying hens fed diets with CPO weighed more than those from hens fed SO ($p<0.05$). However, there was no effect of oil source on egg yolk weight and HU ($p>0.05$).

Temperature of storage reduced significantly the weights of egg, albumen and yolk, as well as HU ($p<0.05$). The heaviest eggs, albumens and yolks were found in eggs stored at 4°C, and the lowest in eggs stored at 24°C. Haugh units shows a significant interaction of oil source x storage temperature ($p<0.05$). This interaction denotes that eggs from laying hens fed diets with CPO had lower HU than hens fed diets with SO (Figure 1).

Days in storage affected negatively the weights of eggs and albumen ($p<0.05$). As days in storage increased, the weights of eggs and albumen was reduced, whereas, yolk weight increased conforming days of storage increased ($p<0.05$). Significant interaction of oil source x storage time for HU was found ($p<0.05$). This interaction denotes that HU of eggs from hens fed diets with CPO was higher after 12 days of storage, in comparison to eggs from hens fed diets with SO.

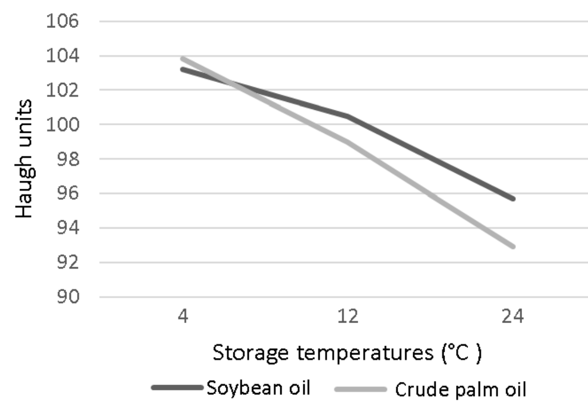

Figure 1. Interaction oil x storage temperature for the Haugh units measurements

Table 2. Effect of source of oil in the diet, storage temperature and days in storage on weight of eggs, albumen, yolk and Hugh units.

Oil	Weight (g)			Haugh units
	Egg	Albumen	Yolk	
Soybean	57.6ª	35.6ª	14.1ª	99.8ª
Palm	58.7ᵇ	36.9ᵇ	13.9ª	98.6ª
SEM[1]	0.016	0.011	0.004	0.027
p	0.0259	0.0038	0.2858	0.1253
Storage temperature				
4°C	59.7ª	36.8ªᵇ	14.6ª	103.5ᶜ
12°C	58.3ᵇ	36.3ᵇ	13.9ᵇ	99.8ᵇ
24°C	56.6ᶜ	35.6ᵇ	13.3ᶜ	94.3ª
SEM	0.020	0.017	0.006	0.034
p	0.0001	0.0001	0.0001	0.0001
Days of storage				
0	58.4ᵇ	37.2ª	13.1ᵇ	110.7ª
4	59.3ᵇ	36.4ªᵇ	14.2ª	100.2ᵇ
8	59.5ᵇ	36.2ᵇ	14.3ª	93.9ᶜ
12	55.6ª	35.4ᵇ	14.4ª	92.0ᶜ
SEM	0.027	0.023	0.008	0.045
p	0.0001	0.0001	0.0001	0.0001
Interactions				
Oil x ST[1]	0.7851	0.8771	0.7710	0.0462
Oil X DS[2]	0.5810	0.8778	0.5737	0.0004

[1] Standard error of the mean; [2] ST=Storage temperature
[3] DS=Days in storage
Means in the same column with different superscripts differ significantly ($p<0.05$)

Quality traits of albumen and yolk. The effects of source of oil in the diet, storage time and temperature on albumen and yolk traits are shown in table 3. The oil source in the diet did not affect any of the traits measured in the albumen or the yolk ($p>0.05$). However, an effect of storage temperature was found ($p<0.05$). Albumen width and length and yolk width increased as storage temperature increased from 4 to 24°C ($p<0.05$), but, albumen and yolk height was reduced ($p<0.05$).

Table 3. Effect of source of oil in the diet, storage temperature and storage period on albumen and yolk measurements.

Oil	Albumen measurements (mm)			Yolk measurements (mm)	
	Width	**length**	**Height**	**Width**	**Height**
Soybean	62.3^{a}	79.4^{a}	10.1^{a}	36.8^{a}	15.4^{a}
Palm	63.3^{a}	80.7^{a}	10.0^{a}	36.7^{a}	15.4^{a}
SEM[1]	0.024	0.024	0.008	0.007	0.003
p	0.1603	0.0652	0.4161	0.5465	0.8094
Storage temperature					
4°C	59.6^{a}	74.7^{a}	11.0^{a}	36.1^{a}	16.0^{a}
12°C	61.8^{b}	79.8^{b}	10.1^{a}	36.6^{b}	15.4^{b}
24°C	66.9^{c}	85.6^{c}	9.0^{b}	37.4^{c}	14.6^{c}
SEM	0.026	0.033	0.007	0.010	0.006
p	0.0001	0.0001	0.0001	0.0001	0.0001
Days of storage					
0	56.2^{a}	68.8^{a}	12.6^{a}	35.8^{a}	15.6^{a}
4	60.9^{b}	80.3^{b}	10.1^{b}	36.8^{b}	15.2^{ab}
8	65.5^{c}	85.0^{c}	8.9^{c}	37.1^{bc}	15.4^{b}
12	68.5^{d}	86.3^{c}	8.5^{c}	37.4^{c}	15.2^{b}
SEM	0.034	0.044	0.010	0.013	0.008
p	0.0001	0.0001	0.0001	0.0001	0.0035
Interactions					
Oil x ST[2]	0.4475	0.1331	0.0752	0.3042	0.8939
Oil X DS[3]	0.6287	0.8642	0.0035	0.5781	0.7546

[1] Standard error of the mean; [2] ST=Storage temperature
[3] DS=Days in storage
Means in the same column with different superscripts differ significantly ($p<0.05$)

An increase in width and length of the albumen was observed as the days of storage increased ($p<0.05$). Similar results were observed for yolk width ($p<0.05$). In contrast, albumen and yolk height decreased as storage temperature increased from 4 to 24°C ($p<0.05$). However, it is necessary to point out, the significant interactions of oil source x storage temperature and oil source x storage time ($p<0.05$) (Figura 2). Those interactions indicate that albumen height of eggs from hens fed diets with CPO declined more as storage temperature increased, in comparison to the albumen from eggs of hens fed diets with SO (Figure 3). However, albumen height of eggs from hens fed diets with CPO was highest at day 12 of storage than those from hens fed diets with SO (Figure 4).

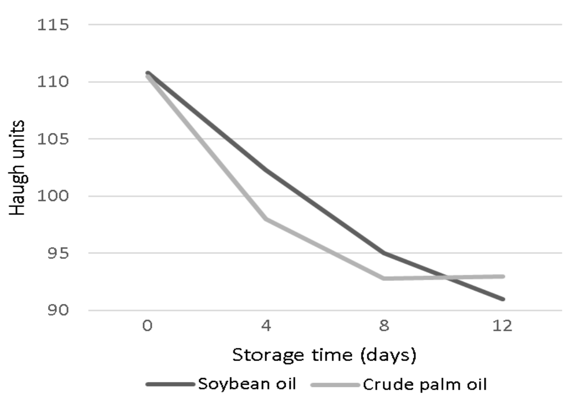

Figure 2. Interaction oil x storage time for the Haugh units measurements.

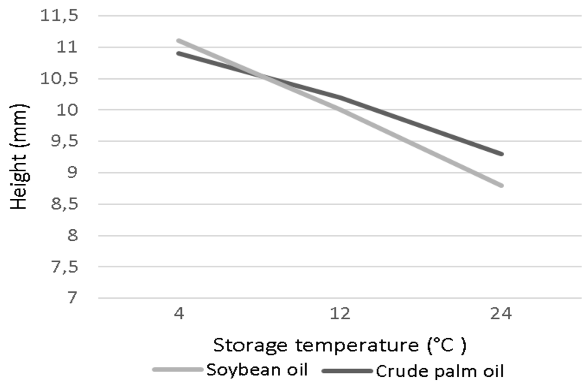

Figure 3. Interaction oil x storage temperature for the albumen height.

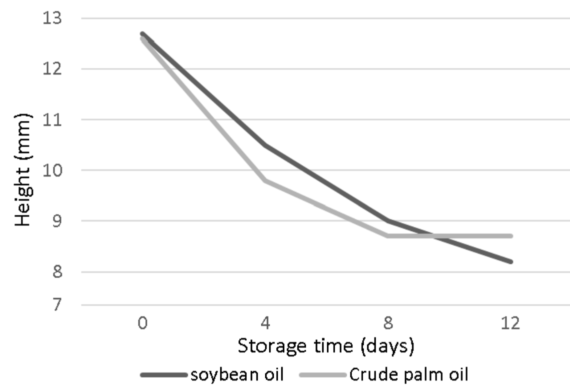

Figure 4. Interaction oil x storage time for the albumen height

Yolk pH and colour. The effect of oil source in the diet of laying hens, storage time and temperature on pH and colour of yolk are shown in table 4. There was no significant effect of oil source on yolk pH and colour ($p>0.05$). Increases of storage temperature produced a reduction of yolk pH and colour, as storage temperature increased ($p<0.05$). The pH of the yolk rise and the color of the yolk deteriorated considerably from 12.8 at day 0 to 8.5 after 12 days of storage ($p<0.05$). Significant interaction of oil source x storage time, denote that yellowness of yolk in hens fed diets with CPO was higher than for hens in diets with SO at day 12 of storage (Figure 5).

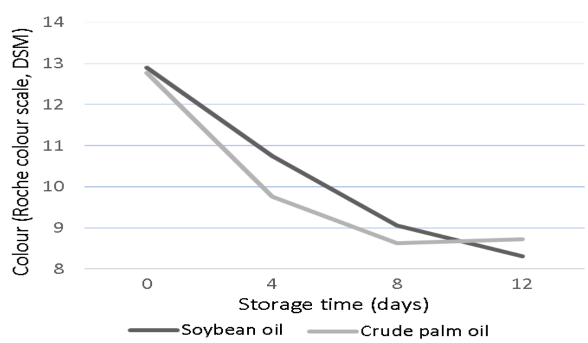

Figure 5. Interaction oil x storage time for yolk colour.

Table 4. Effect of source of oil in the diet, storage temperature and storage time on yolk pH and colour.

Oil	Yolk	
	pH	**Colour**
Soybean	7.6[a]	10.3[a]
Palm	7.7[a]	10.0[a]
SEM[1]	0.002	0.006
p	0.0574	0.1179
Storage temperature		
4°C	7.7[a]	11.0[a] ± 1.76
12°C	7.6[b]	10.2[b] ± 2.36
24°C	7.6[b]	9.2[c] ± 2.77
SEM	0.003	0.008
p	0.0028	0.0001
Days in storage		
0	7.5[a]	12.8[a] ± 1.14
4	7.6[ab]	10.3[b] ± 2.11
8	7.7[b]	8.8[c] ± 1.69
12	7.7[b]	8.5[c] ± 1.93
SEM	0.003	0.010
p	0.0117	0.0001
Interactions		
Oil x ST[2]	0.2760	0.0627
Oil X DS[3]	0.0579	0.0005

[1] Standard error of the mean; [2] ST=Storage temperature
[3] DS=Days in storage
Means in the same column with different superscripts differ significantly ($p<0.05$)

DISCUSSION

Egg quality traits and Haugh units. The highest egg weight and albumen found in this work in hens fed CPO diets, compared to those fed SO (Table 2) coincide with Njoku and Nwazota (10) who found that hens fed diets with palm oil had heavier eggs in comparison to those fed diets with SO. In other research report no differences between using soybean or palm oil in the diet were observed on egg weight (17). Although, CPO have 50% of saturated fatty acids (9), which have low metabolizable energy value in poultry (18), there is evidence that mixing saturated and unsaturated fatty acids in the diet of poultry improve metabolizable energy value (18,19). Then, CPO that have a natural mixture of satured and unsatured fatty acids, can be used in laying hen diets to improve egg weight and albumen, as was observed in this experiment.

Reduction in egg, albumen and yolk weight conforming storage temperature increased from 4 to 24°C, observed in this experiment agree with previous reports (1,2). The reductions in weight have been associated to increase in moisture losses from the eggs as storage temperature increases (20,21,22). Similarly, when storage time is lengthened, moisture losses from the eggs increase (21,23). The moisture loss contributes to losses in egg and albumen weights as observed in this experiment (Table 3). However, in this experiment, conforming days of storage increased, yolk weight increased 10% (Table 3). This effect has been reported before and it is related to material and water from albumen that passed through the yolk, because of weakening of the vitelline membrane, as storage time increases (24,25).

Significant interaction of oil source x storage temperature and oil x storage time ($p<0.05$) suggest that supplementation in the diet of hens with SO kept higher HU than CPO at different storage temperatures, but, use of CPO had higher HU than SO when storage time was extended (Figure 2). These finding could be related to content of vitamin E reported for CPO that can reduce oxidative process (12,13,14), mainly when storage time is lengthened. Those results make sense, because lipo-soluble vitamins, like vitamin E, denaturalized easily at warm temperatures. Therefore, if eggs are stored at room temperature, the antioxidant effects of the CPO could not be observed, but, if eggs are stored at 4°C, egg quality could be preserved for longer time.

Quality traits of albumen and yolk. Albumen and yolk width and height, and albumen length were affected by storage temperature. The reduction in albumen height was inversely correlated to increases in albumen width and length, conforming storage temperature increased (Table 3). These results agree with other reports (25,26,27,28). During storage, the gelatinous structure of the thick albumen gradually liquefies, making it thinner (23,29). As it happens in albumen, the height of yolk was reduced and width increased as storage temperature increased (Table 3). It has been reported that an increase in storage temperature reduces the yolk strength of vitelline membrane, which results in widening and flattening of yolk (30,31).

Similar effects occur with storage time; as the days in storage increased, the vitelline membrane strength of the yolk was reduced and became wider and flatter (31). The increase in storage time, increased progressively, the weakening of the vitelline membrane and liquefaction of the yolk, caused mainly by water diffusion from the albumen, which results in a widening and flattening of the yolk (22,25,29).

Significant interactions of oil source x storage temperature and oil source x storage time for albumen height (Figures 3 and 4), shows that albumen was highest in eggs of hens supplemented with SO at 24°C than those given CPO. However, albumen stored 12 days was highest in eggs of hens supplemented CPO in comparison to those supplemented SO. As mentioned above, the effect of CPO was not observed when the storage temperature was 24°C, because of the oxidative role of vitamin E, but, after 12 days of storage and when temperatures were not so high, the quality of albumin last longer.

Yolk pH and colour. Eggs recently laid have an initial albumen pH of 7.4 to 8.6, and are CO_2 satured. In this experiment pH increased as temperature rise from 4 to 24°C and storage time lengthens (Table 4). Those results agree with previous reports (22,23,27). The increase in albumen pH is associated to loss of CO_2 via eggshell pores (22,23,27).

Reduction in yolk colour, observed in this experiment, as storage time and temperature increased (Table 4), have been reported previously (22). Yolk colour is chiefly dependent upon the content of yolk carotenoids, which can be degraded by oxidative processes, varying the yolk pigmentation during storage (22). Diffusion of water from albumen to the yolk with longer storage time and high storage temperature, accelerate oxidative process of yolk pigment (22,30).

The significant interaction of oil source x storage time for yolk colour, suggest that yolk from eggs of hens fed diets supplemented with CPO held a better yellow colour than yolk from eggs of hens supplemented with SO, when storage was for longer time. These finding suggest that probably vitamin E from CPO could reduce oxidative process and preserve yolk color during more time (12,13,14).

In conclusion eggs and albumen from hens given CPO in the diet were heavier than those given SO. The increase of storage temperatures from 4 to 24°C and time of storage from 0 to 12 days reduced egg, albumen and yolk weights. In general, egg quality deteriorates as both storage time and temperature increased. However, interactions observed here, suggest that CPO supplementation of laying hens kept egg quality characteristics, like HU, albumen height and yolk color, when storage last longer (12 days).

Conflict of interests

There is no conflict of interest.

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