**ABSTRACT**

The present study aimed to evaluate increasing levels of fish waste oil in laying hens diets on performance, egg quality, and sensory features of the eggs. 192 Hisex White laying hens with 29 weeks of age were used, with water and food ad libitum. The experimental design was completely randomized consisting of eight treatments corresponding to the inclusion levels of fish waste oil (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5%) in the diets, with four replicates of six birds each. Data collected were subjected to polynomial regression at 5% of significance. Differences (p<0.05) were observed in feed intake and egg mass. Feed intake increased until 2.50% of fish waste oil in the diets. Differences were not observed (p>0.05) in all variables analyzed. Differences were observed (p<0.05) in flavor. Eggs from birds fed diets up to 2.00% present better acceptance by the tasters. Above this level, there was a considerable drop in acceptance. From these results, the present study indicates that the use of fish waste oil in laying hens diets did not affect the egg quality. However, its high inclusion negatively affected the feed intake, egg mass, and egg flavor.

**INTRODUCTION**

In the last years, there was a significant growth in the Brazilian aquaculture, especially in the Northern region. This large volume of production indicates a considerable amount of waste that represents a significant potential to be used in animal feed (Anjos et al., 2015; Arruda, 2017). However, the use of fish waste as alternative feed in poultry diets is not an innovation in the poultry industry, especially due to their large use in regions that present logistics barriers to grain and high-cost feedstuffs (Jafari et al., 2006; Cruz et al. 2016).

In general, fish oils are rich sources of omega-3 fatty acids and poor sources of omega-6, and the contents of linoleic acid are also low (Mariod et al., 2015). Currently, omega-3 fatty acid-rich fish oil has been widely used in food, pharmaceutical and in the health products industry, especially in the European and American market. At the same time, scientists in the animal nutrition field hoped to diversify the source of omega-3 fatty acid alternative to fish products (Dong et al., 2018).

Furthermore, previous studies pointed that the use of fish oils and fats in poultry feed may affect the energy metabolism, improve the diet's palatability, and regulate the digestibility of nutrients (Carvalho, 2006; Cherian et al., 2007; Pita, 2007; Santos et al., 2009; Feltesv et al., 2010). Their investigations also indicated that the inclusion of various fish oils in hen diets result in significant increase in yolk omega-3 fatty acids.

However, studies about the effect of fish oil on performance and egg quality are relatively limited (Dong et al., 2018), although some
studies using fat sources (soybean oils, linseed, cottonseed, and sunflower, fish fat, animal fat, among others) in hen’s diets did not present negative changes on performance and egg quality (Baucells et al., 2000; Santos et al., 2009; Mariod et al., 2015). The same works also indicating that the major sources of n-6 polyunsaturated fatty acids are vegetable oils, whereas n-3 polyunsaturated fatty acids sources include fish by-products (Schmitz & Ecker, 2008; Mariod et al., 2015). The inclusion of various fish oil in hen diets may result in a significant increase on fatty acids content in yolk, producing the named “enriched eggs” (Gonzalez-Esquerra & Leeson, 2000; Cherian et al., 2002; Cherian et al., 2007), a popular trend in the worldwide market (Dong et al., 2018).

It is important to mention that lipid degradation may cause a deterioration of the biological content in the eggs and change several properties such as the sensory quality (flavor, aroma, texture, and color), nutritional value, storage time (Araújo, 1999; Saleh, 2013), among others. And the use of oils containing high polyunsaturated fatty acids content may help to avoid these problems and positively affect the egg quality (Pacheco, 2005). The dietary inclusion of fatty acids in poultry diets may be a great advantage to consumers and the poultry industry if commercially acceptable levels of their use could be established (Shin et al., 2011). Thus, the objective of this study was to evaluate increasing levels of fish waste oil in diets for laying hens on performance, egg quality, and sensory features of the eggs.

**MATERIAL AND METHODS**

The experimental procedures were developed in the facilities of the Poultry Sector, College of Agrarian Sciences, Federal University of Amazonas, Manaus, Amazonas State, Brazil. All procedures were approved by the Ethics Committee in Use of Animals (protocol number 012/2017) of Federal University of Amazonas.

The experiment period lasted 105 days divided into five periods of 21 days. The birds were subjected to a previous adaptation period of seven days to the diets and facilities. The aviary (17.0 x 3.5 m) used had galvanized wire cages, trough feeders, and nipple drinkers.

192 Hisex White laying hens with 29 weeks-of-age were used. Birds were weighed in the beginning of the experimental period to standardize the plots, presenting an average weight of 1.45± 0.0025kg. Egg collection was performed two times a day (9 a.m. and 3 p.m.). The temperature and relative humidity were recorded two times a day (9:00 a.m. and 3:00 p.m.) using a digital term-hygrometer positioned above the birds’ cage, with average results of 30.38 °C and 67.13%, respectively. The experimental design was completely randomized constituted by eight treatments corresponding to the inclusion levels of fish waste oil (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5%) in the diets, with four replicates of six birds each. Throughout the experimental period, 16 hours of light/day (12 natural hours + 4 artificial hours) were provided to the birds.

The fish waste oil was from the fish processing plant of RIOMAR®, Itacoatiara town, Amazonas State, Brazil. This product was obtained from pressing of freshwater fish waste (head, bone structure, fins, tissue, and visceral residue) in the industrial level. The composition and fatty acids profile of fish waste oil was determined in the CBO Laboratories® (Campinas, São Paulo, Brazil), and its results are present in Table 1.

| Components Composition | Components Composition |
|------------------------|------------------------|
| Palmitic acid (C16:0), % | 29.01                  |
| Stearic acid (C18:0), %  | 9.62                   |
| Oleic acid (C18:1n9c), % | 18.48                  |
| Linoleic acid (C18:2n6c) | 4.39                   |
| Alpha Linolenic acid LNA (C18:3n3) | 4.51 |
| Arachidonic acid AA (C20:4n6) | 3.09                 |
| Eicosapentaenoic acid (C20:5n3) | 3.26                   |
| Docosahexaenoic acid DHA (C22:6n3) | 4.20                   |
| Omega 3, %              | 12.79                  |
| Omega 6, %              | 8.57                   |
| Omega 9, %              | 20.37                  |
| Monounsaturated fat, %  | 28.92                  |
| Polyunsaturated fat, %  | 21.91                  |
| Unsaturated fat, %      | 50.83                  |
| Saturated fat, %        | 48.23                  |
| Humidity and volatiles, % | 0.19             |
| Thietyl extract, %      | 99.06                  |
| Acidity, %              | 13.38                  |
| Peroxide index, meq/kg  | 4.36                   |
| Iodine index, meq/kg    | 85.37                  |

The experimental diets were formulated according to the nutritional requirements of laying hens according to Rostagno et al. (2017), using the composition obtained for fish waste oil (Table 2).

From data collected during the 105 days of the experimental period, we calculated the feed intake (g/bird/day), egg production (%), feed efficiency (kg of feed used / kg of egg), feed efficiency (kg of feed used / dozen eggs), and egg mass (g). In the end of each 21 days period, four eggs of each plot were randomly selected to evaluate egg weight (g), albumen (%), yolk...
Fish Waste Oil in Laying Hens Diets

The eggs were stored for one hour in room temperature and weighed using an electronic balance (0.01 g). The eggs were placed in wire baskets and immersed in buckets containing different levels of sodium chloride (NaCl) with density variations from 1.075 to 1.100 g/cm³ (interval of 0.005) to evaluate the specific gravity.

Then, the eggs were placed on a flat glass plate to determine albumen and yolk height, and yolk diameter using an electronic caliper. The yolk values (diameter and height) were used to determine the yolk index. To separate the albumen and the yolk a manual separator was used. Each one was placed in a plastic cup and weighted in an analytical balance.

Eggshells were washed, dried in an oven (50 ºC) for 48 hours, and weighed. Dry eggshells were used to determine the eggshell thickness using a digital micrometer. Average eggshell thickness was analyzed considering three regions: basal, meridional, and apical.

Then, the eggs were placed on a flat glass plate to determine albumen and yolk height, and yolk diameter using an electronic caliper. The yolk values (diameter and height) were used to determine the yolk index. To separate the albumen and the yolk a manual separator was used. Each one was placed in a plastic cup and weighted in an analytical balance.

Eggshells were washed, dried in an oven (50 ºC) for 48 hours, and weighed. Dry eggshells were used to determine the eggshell thickness using a digital micrometer. Average eggshell thickness was analyzed considering three regions: basal, meridional, and apical.

The yolk color was evaluated using a ROCHE© colorimetric fan with a scale of 1 to 15. Haugh unit was calculated using the egg weight and albumen height values in the formula $H_{\text{unit}} = 100 \times \log (H + 7.57 - 1.7 \times W0.37)$, where $H$ = albumen height (mm), and $W$ = egg weight (g).

To evaluate the sensory features of the eggs, a 9-point hedonic test (acceptability) was used. The scale considered the extremes “I liked it very much” (9) and “disliked it very much” (1), characterizing a preference test (Dutcosky, 1996). 45 untrained and voluntary tasters evaluated a sample (half of a boiled egg in hot water for 10 minutes) of each treatment. The aroma, color, flavor, and appearance were evaluated.

All data collected in this study were analyzed using the GLM procedure of SAS (Statistical Analysis System, v. 9.2) and estimates of treatments were subjected to ANOVA and subsequent polynomial regression analysis. Results were considered significant at $p \leq 0.05$.

RESULTS

Feed intake ($y = -1.5262x^2 + 2.6893x + 102.74$ $R^2 = 0.77$) decreased 3.50% with fish waste oil in the diets. There was also a considerable reduction in egg production ($y = -1.3417x^2 + 1.7665x + 94.482$ $R^2 = 0.72$), and egg mass ($y = -1.6148x^2 + 2.1279x + 54.563$ $R^2 = 0.65$) of 3.50% with the inclusion of fish waste oil in the diets. The inclusion level of 2.00% of fish waste oil presented more balanced results than other inclusion levels (Table 3).

Differences were not observed ($p>0.05$) in all variables analysed. The inclusion of fish waste oil in the diets did not affect the egg quality (Table 4).

Table 2 – Diets composition containing fish waste oil.

| Ingredients          | 0         | 0.5       | 1.0       | 1.5       | 2.0       | 2.5       | 3.0       | 3.5       |
|----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Corn (7.88%)         | 65.0529   | 63.7356   | 62.5469   | 60.5696   | 58.2469   | 55.2459   | 54.3412   | 52.1422   |
| Soybean meal (46%)   | 23.2198   | 23.2741   | 23.3068   | 23.1381   | 22.6938   | 22.1048   | 22.6845   | 22.0501   |
| Wheat meal           | 0.0000    | 0.5000    | 1.0000    | 2.5000    | 5.0000    | 7.5000    | 7.5000    | 10.0000   |
| Fish waste oil       | 0.0000    | 0.5000    | 1.0000    | 1.5000    | 2.0000    | 2.5000    | 3.0000    | 3.5000    |
| Limestone            | 8.8070    | 9.0744    | 9.2352    | 9.3998    | 9.2005    | 9.4005    | 9.6488    | 9.5122    |
| Dicalcium phosphate  | 1.9812    | 1.9760    | 1.9706    | 1.9520    | 1.9195    | 1.9095    | 1.8877    | 1.8568    |
| Vit. min. supplement | 0.5000¹   | 0.5000¹   | 0.5000¹   | 0.5000¹   | 0.5000¹   | 0.5000¹   | 0.5000¹   | 0.5000¹   |
| Salt                 | 0.3500    | 0.3500    | 0.3500    | 0.3500    | 0.3500    | 0.3500    | 0.3500    | 0.3500    |
| DL-methionine (99%)  | 0.0891    | 0.0899    | 0.0905    | 0.0905    | 0.0893    | 0.0893    | 0.0878    | 0.0878    |
| Total                | 100.00    | 100.00    | 100.00    | 100.00    | 100.00    | 100.00    | 100.00    | 100.00    |

| Nutrient | Nutritional levels |
|----------|--------------------|
| M.E., kcal kg⁻¹ | 2,727.3  2,736.7  2,750.5  2,750.5  2,745.7  2,750.5  2,750.5 |
| Crude protein, % | 16.000    16.000    16.000    16.000    16.000    16.000    16.000    |
| Calcium, % | 3.900    3.900    3.900    3.900    3.900    3.900    3.900    |
| Available phosphorus, % | 0.450    0.450    0.450    0.450    0.450    0.450    0.450    |
| Methionine, % | 0.344    0.344    0.344    0.344    0.342    0.342    0.342    |
| Met. +cystine, % | 0.600    0.600    0.600    0.600    0.600    0.600    0.600    |
| Sodium, % | 0.156    0.156    0.156    0.156    0.156    0.156    0.155    |

¹Guaranteed levels per kilogram of the product: Vitamin A 2,000,000 IU, Vitamin D3 400,000 IU, Vitamin E 2,400 mg, Vitamin K3 400 mg, Vitamin B1 100 mg, Vitamin B2 760 mg, Vitamin B6 100 mg, Vitamin B12 2,400 mcg, Niacin 5,000 mg, Calcium Pantothenate 2,000 mg, Folic acid 50 mg, Coccidiostat 12,000 mg, Choline 50,000 mg, Copper 1,200 mg, Iron 6,000 mg, Manganese 14,000 mg, Zinc 10,000 mg, Iodine 100 mg, Selenium 40 mg. Vehicle q.s.p. 1,000 g.
Differences were observed ($p<0.05$) in flavor. Eggs from birds fed diets up to 2.00% of fish oil presented better acceptance by the tasters. Above this level, there was a considerable drop in acceptance of the eggs. The inclusion level of 2.00% of fish waste oil provided eggs with better flavour (Table 5).

**Table 3** – Feed intake (FI), egg production (EP), feed efficiency (FE, kg.kg$^{-1}$ and kg.dz$^{-1}$), and egg mass (EM) of laying hens fed diets containing fish waste oil.

| Variables     | Fish waste oil levels (%) | $p$-value | Effect | CV, % |
|---------------|---------------------------|-----------|--------|-------|
| FI, g/bird/day| 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 |           |        |       |
|               | 101.52 103.83 102.02 102.98 103.25 102.19 101.75 94.78       | 0.01 Q    | 2.41   |
| EP, %         | 94.76 94.60 94.12 94.52 93.45 93.45 93.57 84.96       | 0.01 Q    | 1.94   |
| FE, kg.kg$^{-1}$ | 1.78 1.79 1.79 1.80 1.77 1.77 1.75 1.81     | 0.68 -     | 2.55   |
| FE, kg.dz$^{-1}$ | 1.28 1.32 1.30 1.30 1.32 1.31 1.30 1.36     | 0.21 -     | 2.91   |
| EM, g         | 54.05 54.96 53.51 54.01 54.37 53.83 54.16 44.09     | 0.01 Q    | 2.49   |

CV – Coefficient of variation. $p$-value – Coefficient of Probability. Q – Quadratic.

**Table 4** – Egg weight (EW), %albumen (AB), %yolk (YO), %shell (SH), albumen height (AH), yolk height (YH), yolk index (YI), shell thickness (ST), specific gravity (SG), Haugh unit (HU), and yolk color (YC) of eggs from laying hens fed diets containing fish waste oil.

| Variables     | Fish waste oil levels (%) | $p$-value | Effect | CV, % |
|---------------|---------------------------|-----------|--------|-------|
| EW, g         | 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 |           |        |       |
|               | 57.56 58.68 57.14 57.71 58.79 57.98 58.46 58.14       | 0.39 -     | 1.82   |
| AB, %         | 60.45 61.22 60.38 60.69 61.50 61.12 60.89 60.39       | 0.57 -     | 1.53   |
| YO, %         | 26.55 26.34 26.94 27.26 26.72 27.37 26.75 27.11       | 0.28 -     | 2.31   |
| SH, %         | 9.81 9.73 9.95 9.91 9.86 9.73 9.85 9.71       | 0.50 -     | 1.86   |
| AH, mm        | 9.72 9.58 9.69 9.53 9.71 9.99 9.52 9.48       | 0.14 -     | 2.57   |
| YI            | 0.38 0.40 0.40 0.40 0.40 0.41 0.40 0.40       | 0.17 -     | 3.24   |
| ST, µm        | 0.45 0.45 0.45 0.46 0.46 0.45 0.45 0.46       | 0.06 -     | 1.51   |
| SG, g/mL      | 1092.1 1091.9 1091.9 1091.4 1090.8 1091.3 1090.7 1090.7       | 0.06 -     | 0.80   |
| HU            | 61.39 62.61 60.77 61.36 61.90 61.54 62.12 61.81       | 0.65 -     | 2.11   |
| YC            | 6.01 6.11 5.91 5.86 6.10 6.16 6.00 5.81       | 0.09 -     | 2.97   |

CV – Coefficient of variation. $p$-value – Coefficient of Probability.

**DISCUSSION**

The present study indicated that high levels of fish waste oil decreased hen’s performance due to the negative effect caused on feed intake. Different fat sources are available in poultry diets, being from vegetable or animal sources, where the industry observed that diets containing fish oil caused lower feed intake and body weight, and worst feed efficiency (Sahito et al., 2012; Ayed et al., 2015). Previous studies indicated that dietary supplemented with high levels of fish oil had only significant effects on layer performance, especially on feed intake (Saleh, 2013). Silva et al. (2017) reported a significant effect in feed intake, egg production, and egg weight from inclusion of fish by-product in laying hen’s diets, corroborating with our results. Faitarone et al. (2013) also commented that the high inclusion of oil in hens’ diets cause a significant reduction on the feed intake, attributing this result to high percentages of long-chains of polyunsaturated fatty acids in fish oil that transfer their sensory characteristics to the diets, changing their palatability (Ayed et al., 2015). Normally, oils of animal origin, such as fish oil, tend to cause a larger effect in feed intake than oils of vegetal origin (Bertipaglia et al., 2016; Silva et al., 2017), attributing this effect to peculiar odor
and flavor that these by-products transfer to the diets from their polyunsaturated fatty acids (Freitas et al., 2013, Nogueira et al., 2014).

On the other hand, there was no effect of fish waste oil on the quality of the egg, both lower and higher levels. Previous studies reported that the quality of the eggs is the most affected feature by the inclusion of fish oil in poultry diets, especially the yolk (Oliveira et al., 2010). Grobas et al. (2001) reported an increase in the weight of eggs produced by laying hens fed diets with different lipid sources, indicating that this addition was sufficient to promote this increase. This small increase in egg weight may occur due to a little deposition of fat in the yolk, especially linoleic acid (Keshavarz & Nakajima, 1995; Grobas et al. 1999). According to Keshavarz & Nakajima (1995), this increase in egg weight may also be related to changes in the nutrients absorption by the hens caused by the increase of passage rate provided by the fat source used. Furthermore, it is known that the fatty acids deposited in the yolk are reflects of dietary fatty acid levels, where these variations in yolk fatty acids are directly caused to changes in the dietary fatty acids levels (Cachaldora et al., 2006; Kralik et al., 2008; Nogueira et al., 2014).

Hester (1999) and Muramatsu et al. (2005) suggested that the inclusion of oils in laying hens diets should be carefully calculated due to the fact that high levels of inclusion may negatively affect the eggshell quality. The same authors reported that a high inclusion of oils in poultry diets interfere on mineral metabolism, especially in the retention and absorption of calcium due to the formation of insoluble soaps during the digestion process, hindering its good use by the birds. However, some studies pointed that the addition of oils in laying hen’s diets may not represent a significant change in some internal or external structures of the egg (Mazalli et al., 2004; Filardi et al., 2005; Dong et al., 2018), such as observed in this study.

And even the inclusion of fish waste oil did not affect the egg quality, we observed a significant effect on the sensory features, especially in the flavor. Previous research has shown that hens fed with fish by-products resulted in tainted eggs with a “fishy” taste (Holdas & May, 1966; Cherian et al., 2002; Hargis et al., 1993; Coorey et al., 2014; Dong et al., 2018). However, Cherian et al. (2007) reported that the inclusion of fish oil in the hens’ diets resulted in worst egg flavor and indicated that this fish by-product is directly responsible for sensory changes in the eggs.

Naturally, fish oil contains high percentages of long-chain polyunsaturated fatty acids, which accounts for the oxidative instability and the transference of characteristic fish flavor to the meat or eggs of birds fed fish oil. In general, fish oils are rich sources of omega-3 fatty acids and poor sources of omega-6, and the contents of linoleic acid are also low (<2%) (Baião & Lara, 2005). For hens, the fatty acids are incorporated into the yolk, making it more susceptible to lipid degradation caused by oxidation, hydrolysis, polymerization, or pyrolysis. These processes change several features of the egg, especially the flavor, aroma, texture, and color (Bobbio & Bobbio, 1992; Araújo, 1999; Coorey et al., 2014).

The enriched eggs with a great amount of fatty acids may present most susceptible to lipid oxidation, mainly due to polyunsaturated fatty acids and its double bonds (Gómez, 2003). Faitarone (2010) reported that eggs enriched with polyunsaturated fatty acids from soybean, canola, and linseed oils presented a high degree of lipid oxidation. Furthermore, the oxidative stability depends on unsaturation degree of fatty acids present or their concentration (Pacheco, 2005). The enrichment of eggs through fatty acids from animal or vegetable oils is a positive tool to the poultry industry. However, the oil level cannot be extrapolated, because it may cause a high lipid degradation, and reduce the sensorial acceptance of these eggs by the consumer (Seibel et al., 2010).

**CONCLUSIONS**

The present study indicates that the use of fish waste oil in laying hens diets does not affect the egg quality. The inclusion level of 2.00% of fish waste oil provided more balanced results of performance and better egg flavour. However, its high inclusion negatively affects the feed intake, egg mass, and egg flavor.

**REFERENCES**

Anjos MR, Souza VC, Santiago RC, Machado NG, Biudes MS, Fulan JA. Piscicultura no sudoeste da Amazônia brasileira: o caso de Rondônia em 2009. Global Science and Technology 2015;8(2):143-152.

Araújo JMA. Química de alimentos. Viçosa: UFV; 1999. 416p.

Arruda MCF. Avaliação dos indicadores da política de pesca do programa zona franca verde: perspectivas econômicas e ambientais. Manaus: UFAM; 2017.

Ayed HB, Attia H, Ennouri M. Effect of oil supplemented diet on growth performance and meat quality of broiler chickens. Advanced Techniques in Biology & Medicine 2015;4(1):1000156.
Fish Waste Oil in Laying Hens Diets

Gómez MEDB. Modulação da composição de ácidos graxos poli-insaturados ômega 3 de ovos e tecidos de galinhas poedeiras, através da dieta: estabilidade oxidativa [tese]. São Paulo (SP): Universidade de São Paulo; 2003.

Gonzalez-Esquerra, R, Leeson S. Effect of feeding hens regular or deodorized menhaden oil on production parameters, yolk fatty acid profile, and sensory quality of eggs. Poultry Science 2000;79:1597-1602.

Grobos S, Mateos G, Méndez J. Influence of dietary linoleic acid on production and weight of eggs and egg components in young brown hens. The Journal of Applied Poultry Research 1999;8:17-184.

Grobos S, Méndez J, Lázaro R, de Blas C, Mateo GG. Influence of source and percentage of fat added to diet on performance and fatty acid composition of egg yolks of two strains of laying hens. Poultry Science 2001;80:1171-1179.

Hargis PS, Van Elswyk ME. Manipulating the fatty acid composition of poultry meat and eggs for the health conscious consumer. World's Poultry Science Journal 1993;49(03):251-264.

Hester PY. A qualidade da casca do ovo. Avicultura Industrial 1999;90(1072):20-30.

Holdas A, May KN. Fish oil and fishy flavor of eggs and carcasses of hens. Poultry Science 1966;45(6):1405-1407.

Jafari M, Pirmohammadi R, Bampidis V. The use of dried tomato pulp in diets of laying hens. International Journal of Poultry Science 2006;5(7):618-622.

Keshavarz K, Nakajima S. The effect of dietary manipulations of energy, protein, and fat during the growing and laying periods on early egg weight and egg components. Poultry Science 1995;74:50-61.

Kralik G, Skrtic Z, Suchy P, Straková E. Feeding fish oil and linseed oil to laying hens. Avia Magazine 2009;53(4):561-568.

Mariod AA, Mukhtar MAE, Saiti ME, Hervan T. Effect of addition of fish oil on the performance parameters of laying hens and the fatty acid composition of their egg yolk. American Journal of Food Science and Nutrition 2001;80:1171-1179.

Mazalli MR, Faria DE, Salvador D, Ito DT. A comparison of the feeding value of different sources of fats for laying hens: 1. Performance characteristics. Journal Applied Poultry Research 2004;13:274-279.

Muramatsu K, Stringhini JH, Café MB, Jardim Filho RM, Andrade L, Godoi F. Desempenho, qualidade e composição de ácidos graxos do ovo de poedeiras comerciais alimentadas com rações formuladas com milho ou milho contendo diferentes níveis de óleo vegetal. Acta Scientiarum Animal Sciences 2005;27(1):43-48.

Nogueira MA, Cruz FGG, Tanaka ES, Rufino JP, Santana TM. Suplementação de óleo de dendê (Elaeisguineensis/aquum) na alimentação de poedeiras em clima tropical. Revista Académica: Ciências Agrarias e Ambientais 2014;12(2):103-111.

Oliveira DD, Baião NC, Larrau EN, Figueiredo TC, Lara LC, Lana AMQ. Fontes de lipídios na dieta de poedeiras: desempenho produtivo e qualidade dos ovos. Arquivos Brasileiro de Medicina Veterinaria e Zootecnia 2010;62(3):718-724.

Pacheco SGA. Estabilidade oxidativa de óleo de peixe encapsulado e acondicionado em diferentes tipos de embalagem em condições de armazenamento [dissertação]. Piracicaba (SP): Universidade de São Paulo; 2005.

Pita MCG. Fontes marinhas e vegetais de PUFA em dietas de galinhas poedeiras: efeito na composição lipídica da gema do ovo e tempo de incorporação dos ácidos graxos [tese]. São Paulo (SP): Universidade de São Paulo; 2007.

B邰ão NC, Lara LC. Oil and fat in broiler nutrition. Revista Brasileira de Ciência Avícola 2005;7(3):129-141.

Baucells MD, Crespo N, Barroeta AC, Lópezferrer S, Rashorn MA. Incorporation of different polyunsaturated fatty acids into eggs. Poultry Science 2000;79(1):51-59.

Bertipaglia LA, Sakamoto MI, Bertipaglia LM, Melo GMP. Lipid sources in diets for eggs-laying Japanese quail: performance and egg quality. Acta Scientiarum Animal Sciences 2016;38(3):281-284.

Bobbio PA, Bobbio FO. Química do processamento de alimentos: lipídios. São Paulo: Varela; 1992.

Cachaldora P, García-Rebollar P, Álvarez C, De Blas JC, Méndez J. Effect of type and level of fish oil supplementation on yolk fat composition and n-3 fatty acids retention efficiency in laying hens. British Poultry Science 2006;47(1):43-49.

Carvalho GGP, Veloso CM, Silva FF, Carvalho BMA. Silagem de resíduo de peixe em dietas para aves de tipíapa-do-nilo. Revista Brasileira de Zootecnia 2006;35(1):126-130.

Cherian G, Goeger MP, Ahn DU. Dietary conjugated linoleic acid with fish oil alters yolk n-3 and trans fatty acid content and volatile compounds in raw, cooked, and irradiated eggs. Poultry Science 2002;81:1571-1577.

Cherian G, Traber MG, Goeger MP, Leonard SW. Conjugated linoleic acid and fish oil in laying hen diets: effects on egg fatty acids, thioobarbituric acid reactive substances, and tocopherols during storage. Poultry Science 2007;86:953-958.

Coorey R, Novinda A, Williams H, Jayasena V. Omega-3 fatty acid profile of eggs from laying hens fed diets supplemented with chia, fish oil, and flaxseed. Journal of Food Science 2014;80(1):180-187.

Cruz FGG, Rufino JP, Melo RD, Feijo JC, Damasceno JL, Costa VR. Fontes marinhas e vegetais de PUFAs na dieta de galinhas poedeiras: efeito na composição lipídica da gema do ovo [tese]. São Paulo (SP): Universidade de São Paulo; 2007.

Dong XF, Liu S, Tong JM. Comparative effect of dietary soybean oil, fish oil, and coconut oil on performance, egg quality and some blood parameters in laying hens. Poultry Science 2018;97(7):2460-2472.

Dutcosky SD. Análise sensorial de alimentos. Curitiba: Clube; 2007.

Faitarone ABG, Garcia EA, Roça R, Ricardo H, Andrade EN, Pelícia K, Vercese Dutcosky SD. Análise sensorial de alimentos. Curitiba: Champagnat; 2007.

Faitarone, A.B.G. Fornecimento de fontes lipídicas na dieta de poedeiras e seus efeitos sobre o desempenho, qualidade dos ovos, perfil de ácidos graxos e colesterol na gema [tese]. Botucatu (SP): Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista; 2010.

Feltes MMC, Correia JFG, Beirão LH, Block JM, Ninow JL, et al. Alternativas para a agregação de valor aos resíduos da industrialização de peixe. Revista Brasileira de Engenharia Agrícola e Ambiental 2010;14:669-677.

Filardi RS, Junqueira OM, Laurentzi AC, Casartelli EM, Rodrigues EA, Araújo LF. Influence of different fat sources on the performance, egg quality, and lipid profile of egg yolks of commercial layers in the second laying cycle. Poultry Science 2005;14:258-264.

Freitas ER, Borges AS, Trevisan MTS, Cunha AL, Brás NM, Watanabe PH, et al. Extratos etanólicos de mangá como antioxidantes na alimentação de poedeiras. Pesquisa Agropecuária Brasileira 2013;48(7):714-721.
Fish Waste Oil in Laying Hens Diets

Schmitz G, Ecker J. The opposing effects of n-3 and n-6 fatty acids. Progress in Lipid Research 2008;47:147-155.

Seibel NF, Schoffen AB, Queiroz MI, Souza-Soares LA. Caracterização sensorial de ovos de codornas alimentadas com dietas modificadas. Ciência Tecnologia de Alimentos 2010;30(4):884-889.

Shin D, Narciso-Gaytan C, Park JH, Smith SB, Sanchez-Plata MX, Ruíz-Feria CA. Dietary combination effects of conjugated linoleic acid and flaxseed or fish oil on the concentration of linoleic and arachidonic acid in poultry meat. Poultry Science 2011;90(6):1340-1347.

Silva AF, Cruz FGG, Rufino JPF, Miller WMP, Flor NS, Assante RT. Farinha de resíduo de pescado em ração de poedeiras comerciais leves. Acta Scientiarum Animal Sciences 2017;39(3):273-279.
