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Fish by-product meal in diets for commercial laying hens

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ABSTRACT. This study aimed to evaluate the increasing levels (0, 1, 2, 3 e 4%) of fish by-product meal in diets for laying hens on performance, egg quality and economic analysis. A total of 16052-wk-old *Dekalb White* hens were distributed in a completely randomized design with five treatments and four replicates of eight birds each. The experiment lasted 84 days divided into four periods of 21 days. Estimates of fish by-product meal levels were determined by polynomial regression. Differences ($p < 0.05$) were detected for all variables of performance, in egg weight, yolk and albumen percentage, yolk and albumen height, feed cost and production cost, in which the inclusion of fish by-product meal in the diets showed better results. It can be concluded that fish by-product meal can be used in diets for hens as alternative feed, with better results in egg production, feed conversion, egg weight, yolk-albumen ratio and a reduction in feed cost and production cost.

Keywords: alternative feed, economic available, feed cost, lipid profile, performance.

Farinha de resíduo de pescado em rações de poedeiras comerciais leves

RESUMO. Objetivou-se com este estudo avaliar a inclusão de níveis crescentes (0, 1, 2 3 e 4%) de farinha de resíduo de pescado na dieta de poedeiras comerciais leves sobre o desempenho, qualidade do ovo e análise econômica. Foram utilizadas 160 poedeiras da linhagem *Dekalb White* com 52 semanas de idade. O experimento teve duração de 84 dias divididos em quatro períodos de 21 dias. O delineamento experimental foi o inteiramente casualizado com cinco tratamentos contendo quatro repetições de oito aves cada. As estimativas dos níveis de farinha de resíduo de pescado foram determinadas por meio de regressão polinomial. Foram observadas diferenças ($p < 0,05$) em todas as variáveis de desempenho, no peso do ovo, percentagem de gema e albúmen, altura de gema e albúmen, custo alimentar e custo de produção, onde a inclusão de farinha do resíduo de pescado proporcionou melhores resultados. Concluiu-se que a farinha de resíduo de pescado pode ser utilizada como alimento alternativo em rações para poedeiras comerciais leves, proporcionando melhora na produção de ovos, conversão alimentar, peso do ovo, relação gema-albúmen, redução no custo alimentar e no custo de produção.

Palavras-chave: alimento alternativo, custo, desempenho, perfil lipídico, viabilidade econômica.

Introduction

In a globalized context of growth of both production and consumption of fish, concern with the environmental impacts generated by the production chain and the management of its waste have become issues of general public interest (Arvanitoyannis & Kassaveti, 2008).

Every year, much of the fish production is lost during the capture, industrialization and commercialization, generating a large amount of waste that is dumped directly into the bodies of water or deposited in the urban dumps. In this scenario, technologies for the reuse of these wastes have been studied as alternatives to reduce these environmental problems (Vidotti, Viegas, & Carneiro, 2003; Arruda, Borghesi, & Oetterer, 2007; Mousavi, Mohammadi, Khodadadi, & Keysami, 2013).

Seibel and Souza-Soares (2003) report that in Brazil the reuse of waste from fish processing is still low, and that the fishmeal processed and available on the market is still of poor quality, mainly because this wasteis accumulated in tanks without any type of treatment, which evidence the lack of hygienic quality of these processing plants, or part of it is discarded in the vicinity of the site, contributing to the increasing problem of environmental contamination.

Carvalho, Pires, Veloso, Silva, and Carvalho (2006) and Cunha et al. (2006) still state that animal waste represents a vast source of energy and nutrients that can be converted into ingredients for the animal feed industry. This alternative represents a great potential for use of capture and processing losses of fish processing (up to 60% of the total that is produced and/or caught).

Among the animal production segments, poultry farming may be considered one of the most developed activities in recent times, as a result of advances in genetics, nutrition, sanitation and management. And one of the main goals of poultry production is to efficiently and economically convert the relatively disposable, non-palatable and unattractive raw materials into nutritious foods. The well-balanced diets that use alternative ingredients available at low cost are specifically formulated for countless ages and types of birds (Cruz Pereira Filho, & Chaves, 2006; Loureiro, Rabello, Ludke Júnior, Guimarães, & Silva, 2007; Togashi et al., 2008; Pinheiro et al., 2012).

From this information, the present study aimed to evaluate the inclusion of increasing levels of fish by-product meal in the diet of commercial laying hens on performance, egg quality and economic analysis.

Material and methods

The experiment was conducted at the Poultry Sector of the Department of Animal and Plant Production (DPAV), Faculty of Agricultural Sciences (FCA), Federal University of Amazonas (UFAM), located in the Southern Sector of the University Campus, Manaus, state of Amazonas, Brazil.

This study was approved by the Ethics Committee on Animal Use (CEUA) of Federal University of Amazonas in process with record n. 010/2015.

The experiment lasted 84 days divided into four periods of 21 days. Before the start of the experiment, the birds were subjected to adaptation for seven days period to feed and facilities.

The experimental aviary used had dimensions of 17.0 m in length and 3.5 m in width, containing galvanized wire cages, trough feeders and nipple drinkers. A total of 160 Dekalb White laying hens with 52 weeks of age, and the birds were weighed at the beginning of the experiment in order to standardize the experimental plots, presenting a mean weight of 1.54 ± 0.20 kg. Egg collection was performed twice a day (9 and 15 hours), recording each occurrence (mortality, numbers of eggs, among other information).

The experimental design was completely randomized consisting of five treatments corresponding to the inclusion levels of fish by-product meal (0, 1, 2, 3 and 4%) in the diet, with four replicates of eight birds each. Throughout the experimental period 16 hours of light/day (12 natural hours + 4 artificial hours) were provided to the birds.

The following steps were taken to obtain the fish by-product meal: collection (fish waste: leftovers, viscera, fins and head) obtained from the main species commercialized in the Northern region; selection of the material, remaining only viscera and discarding decomposing material; cooking the material at 62°C; oven drying at 65°C for 72 hours; and finally grinding the material.

The proximate composition of the fish by-product meal was determined at the Fish Technology Laboratory, Faculty of Agricultural Sciences, Federal University of Amazonas, according to the methodologies proposed by Silva and Queiroz (2002) and their results are listed in Table 1.

Table 1. Proximate composition of the fish by-product meal.

Components	Composition
Dry matter, %	90.38
Crude protein, %	51.30
Ether extract, %	33.29
Mineral matter, %	4.39
Total carbohydrates, %	11.02
Gross energy, kcalkg^{-1}	5,105.00
Metabolizable energy, kcalkg^{-1}	3,489.81*

*determined by the calculation for apparent metabolizable energy as described by Rostagno et al. (2011), value expressed in kcal kg^{-1}.

Diets (Table 2) were formulated using the software Supercrac (2004) to meet the nutritional requirements of birds and according to the values of ingredients provided by the Brazilian Tables for Poultry and Swine (Rostagno et al., 2011), except for the composition of fish by-product meal.

For animal performance, we evaluated in each period feed intake (g bird^{-1} day^{-1}), egg production (%), egg mass (g), feed conversion (kg feed per kg egg produced – kg kg^{-1}) and feed conversion (kg feed per dozen eggs produced – kg dz^{-1}). In the last two days of each period, four eggs from each plot were taken at random to evaluate egg quality, in which we analyzed egg weight (g), albumen weight (%), yolk weight (%), albumen height (mm), yolk height (mm), shell thickness (μm) and specific gravity (g cm^{-3}). Before evaluation, the eggs were stored for one hour in order to equalize the temperature to room temperature.

Eggs were weighed on an electronic scale to the nearest 0.01 g. The egg mass was obtained by calculating the quotient between egg weight and egg production multiplied by 100. The whole eggs immediately after weighing were placed in wire baskets and immersed in plastic buckets containing different levels of sodium chloride (NaCl), from the lowest to the highest concentration, with density variations from 1.075 to 1.100 g cm^3, with 0.005-interval. The eggs were removed as they floated to the surface and their respective values were recorded.

Table 2. Composition of diets containing fish by-product meal.

	Levels of fish by-product meal (%)				
Ingredients	0	1	2	3	4
Corn (7.88%)	62.303	62.288	62.272	62.257	62.242
Soybean (46%)	25.657	24.647	23.637	22.626	21.616
Calcitic Limestone	9.239	9.241	9.243	9.245	9.247
Dicalcium phosphate	1.694	1.705	1.715	1.726	1.736
Premix vit. min.[1]	0.500	0.500	0.500	0.500	0.500
DL-methionine (99%)	0.254	0.267	0.280	0.294	0.307
Fish by-product meal	0.000	1.000	2.000	3.000	4.000
Salt	0.350	0.350	0.350	0.350	0.350
Total	100.00	100.00	100.00	100.00	100.00
Items					
ME, kcalkg^{-1}	2,697.00	2,706.49	2,715.40	2,724.33	2,733.23
Crude protein, %	17.000	17.000	17.000	17.000	17.000
Calcium, %	4.000	4.000	4.000	4.000	4.000
Available phosphorus, %	0.400	0.400	0.400	0.400	0.400
Total methionine, %	0.519	0.526	0.532	0.538	0.545
Methionine + cystine, %	0.786	0.786	0.786	0.786	0.786
Total lysine, %	0.861	0.833	0.805	0.776	0.748
Total threonine, %	0.659	0.641	0.623	0.605	0.586
Total tryptophan, %	0.205	0.198	0.192	0.185	0.178
Sodium, %	0.156	0.156	0.156	0.156	0.156

[1]Guaranteed 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, Folicacid 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.

For the analysis of albumen and yolk weight, a manual separator of albumen and yolkwas used. The albumen and the yolk were placed in plastic cups, tared-weight in analytical balance, and weighed. To calculate albumen and yolk weight, they were placed on a flat glass plate to determine their respective values. The criterion for measuring albumen and yolk height is to take measure at the medial region between the outer border of the albumen and the yolk. For measurement of height, an electronic caliper was used; the values are expressed in millimeters. The egg shell weight was obtained after they were washed, dried at room temperature for 48 hours and then weighed in grams.

Dry shells were used to determine the shell thickness, which were measured using a micrometer. The readings were performed in three regions of the shell: basal, meridional and apical, and the values were recorded. From the values obtained in the three regions, the average of the eggshell thickness, in micrometer, was calculated. The egg yolk color was evaluated with the Roche colorimetric fan with a score of 1 to 15. The Haugh unit was determined with the methodology proposed by Nogueira, Cruz, Tanaka, Rufino, and Santana (2014).

In the economic viability analysis, data collected during the productive performance analysis of the hens were used. The economic variables of production analyzed were cumulative feed intake (kg), feed cost (R$), egg production (unit) and cost of egg production (R$).

In order to determine the feed costs and production costs, we used only the values per kilo of the raw materials used and the updated price of these in the region during the period of the experiment (March to May 2016), which were: corn, R$ 0.30; soybean meal, R$ 1.20; limestone, R$ 0.41; dicalcium phosphate, R$ 1.92; common salt, R$ 0.40; DL-Methionine, R$ 12.50; L-Lysine, R$ 10.80; and mineral and vitamin supplement, R$ 9.98. In order to calculate the cost of fish by-product meal, only the transport and handling costs of the product were taken into account, since they are easily obtained in the fish marketing establishments of the region and the price per kilo of the product was estimated at R$ 0.55.

Fixed costs did not change in the short term during the experimental period and were considered constant for all treatments. The methodology used for economic viability analysis was determined according to the formulas proposed by Rufino et al. (2015).

Data collected were tested by analysis of variance with the GLM procedure of the Statistical Analysis System (Statistical Analysis System [SAS], 2008) software and subjected to the polynomial regression analysis at the 5% level of significance.

Results and discussion

There were significant differences ($p < 0.05$) between the means of all variables of productive performance (Table 3) according to the inclusion of fish by-product meal in the diet for laying hens.

Table 3. Feed intake (FI), egg production (EP), feed conversion (FC, kg kg^{-1} and kg dz^{-1}) and egg mass (EM) of laying hens fed diets containing increasing levels of fish by-product meal.

Variables	Levels of fish by-product meal (%)					P-Value	Effect	CV, %
	0	1	2	3	4			
FI, g $bird^{-1}$ day^{-1}	101.81	101.15	103.67	97.95	98.28	0.05	Q	2.94
EP, %	71.63	74.40	74.80	79.76	80.16	0.05	LP	11.01
FC, kg kg^{-1}	2.48	2.27	2.13	1.93	1.86	0.02	LN	12.10
FC, kg dz^{-1}	1.45	1.36	1.40	1.23	1.23	0.02	Q	11.89
EM, g	41.96	44.69	49.04	50.90	53.22	0.04	LP	11.48

CV –Coefficient of variation. P-Value–Coefficient of probability. Q - Quadratic. LP –Positive linear. LN –Negative linear.

The feed intake presented a quadratic effect ($p < 0.05$) ($Y = 100.52 + 1.6569x - 0.4471x^2$; $R^2 = 0.56$), in which from the derivation of the function it was possible to estimate the highest feed intake (102.05 g $bird^{-1}$ day^{-1}) at the inclusion level of 1.85% of fish by-product meal in the diet. These results disagree with Cunha et al. (2006) and Santana-Delgado Avila, and Sotelo (2008), who investigated the inclusion of fish by-products in poultry diets formulated based on crude protein, and found these had a significant influence on the productive performance, with better results in the control diet based on corn and soybean.

In this study, there was an evident change in the feed intake, where the inclusion of fish by-product meal resulted initially in an increased intake, which, according to the aforementioned authors, is because products of animal origin directly affect the palatability of the food, and birds have a predilection for foods with medium to high lipid content (Freitas et al., 2013; Nogueira et al., 2014). Also in this context, a decrease in consumption was observed, which may be related to the energy needs of the birds caused again by the lipid content observed in the composition of fish by-product meal and its effect when included in larger quantity in the diets.

The egg production showed a positive linear effect ($p < 0.05$) ($Y = 69.424 + 2.242x$; $R^2 = 0.92$), where it was verified that the percentage of production increased with increasing inclusion of fish by-product meal in the diet. In this case, the protein increase and the high lipid profile of the fish by-product meal may have assisted in the nutritional enrichment of the diets, where the presence of a variety of nutrients contained in this by-product helps in the stimulation of egg production. Cruz et al. (2006) and Lima et al. (2007), in a similar approach, point out that factors that may affect egg production include food intake and, consequently, the intake of energy and protein by birds and the possibility of nutritional enrichment of diets with alternative ingredients, where direct changes in these relationships can cause actual improvements or decreases in egg production rates.

In feed conversion (kg kg^{-1}), there was a negative linear effect ($p < 0.05$) ($Y = 2.608 - 0.158x$; $R^2 = 0.97$), where the increasing inclusion of fish by-product meal in the diets caused an improvement in feed conversion. On the other hand, feed conversion (kg dz^{-1}) presented a quadratic effect ($p < 0.05$) ($Y = 1.49 + 0.0441x - 0.021x^2$, $R^2 = 0.81$), and the best conversion (1.51 kg dz^{-1}) was achieved with the inclusion of 1.05% of fish by-product meal in the diets. Both feed conversions (kg kg^{-1} and kg dz^{-1}) presented better results as the level of inclusion of fish by-product meal in the diets increased.

Similarly, Hammoumi, Faid, Yachioui, and Amarouch (1998) found positive results when evaluated dried sardine by-product silage in poultry feed and stated that the diets tested yielded performance results similar to or better than those of the reference feed, indicating that the use of by-products from the fish industry may be an interesting alternative in feeding these birds, since as well as the results of this study, that is, levels of inclusion close to 5% can provide improvement in the nutritional quality of the diets, leading to optimization of performance results.

The egg mass presented a positive linear effect ($p < 0.05$) ($Y = 39.343 + 2.873x$; $R^2 = 0.98$), where there was an increase in egg mass with increasing inclusion of fish by-product meal in the diets. These results corroborate with Costa et al. (2009) and Hanna et al. (2013), who also verified significant effect for egg mass from the inclusion of alternative foods in feed. These results obtained for egg mass are directly related to egg production, once this result influences the calculation of the egg mass together with the weight of the egg (Feijó et al., 2016).

In egg quality (Table 4), differences ($p < 0.05$) were detected in egg weight, yolk percentage, albumen percentage, shell percentage, yolk height and albumen height.

The egg weight showed a quadratic effect ($p < 0.05$) ($Y = 61.43 - 0.9639x + 0.5621x^2$; $R^2 = 0.90$), where from the derivation of the function, we observed the best egg weight (61.01 g) at the 0.85% inclusion level of fish by-product meal. These results corroborate with Miller, Cruz, Chagas, Silva, and Assante (2013) and Feijó et al. (2016), who evaluated the inclusion of alternative energy foods in diets for laying hens and affirmed that the inclusion of these in the diets improves egg quality with increase in egg weight and internal and external content.

Table 4. Egg weight (EW), yolk percentage (YP), albumen percentage (AP), shell percentage (SP), albumen height (AH), yolk height(YH), shell thickness (ST), specific gravity (SG) and Haugh unit (HU) of eggs of laying hens fed diets containing increasing levels of fish by-product meal.

Variables	Levels of inclusion of fish by-product meal (%)					P-value	Effect	CV, %
	0	1	2	3	4			
EW, g	61.89	59.69	64.61	67.28	70.14	0.01	Q	3.31
YP, %	30.39	31.21	31.57	30.64	29.89	0.01	Q	1.41
AP, %	50.92	56.32	55.31	57.01	57.19	0.01	Q	4.42
SP, %	9.41	9.88	9.84	9.46	9.40	0.01	Q	2.85
YH, mm	16.53	16.48	17.09	17.60	17.96	0.01	Q	1.60
AH, mm	6.20	6.27	7.01	7.23	7.35	0.01	Q	3.29
ST, μm	37.94	37.67	38.26	37.37	38.54	0.66	ns	3.15
SG, g/mL	1088.28	1087.18	1087.65	1089.53	1086.87	0.44	ns	8.30
HU	86.12	83.9	88.68	91.31	94.15	0.09	ns	4.34

CV – Coefficient of variation. P-Value– Coefficient of Probability. Q –Quadratic effect. ns – non-significant.

These results are associated with those obtained for the yolk percentage that presented quadratic effect ($p < 0.05$) (Y = 28.996 + 1.7416x – 0.3164x2; R2 = 0.93), where from the derivation of the function, the best point of yolk percentage (31.39%) was observed at the 2.75% inclusion level of fish by-product meal in the diets. (Y = 47.516 + 4.6359x -0.5521x2; R2 = 0.81), where from the derivation of the function, we also observed a quadratic effect ($p < 0.05$) (10.04%) at the inclusion level of 0.28% of fish by-product meal.

Bezerra et al. (2015) and Rufino et al. (2015) claimed that the inclusion of foods with medium or high lipid content in the feed for laying hens is directly associated with alterations in the results of yolk percentage due to changes in the lipid metabolism that rules the deposition of these in the yolk, as well as in the results of albumen percentage due to the direct influence of these foods on the balance of the energy-protein ratio, and consequently, on the deposition of albumin for its formation.

Moreover, the yolk height results showed a quadratic effect ($p < 0.05$) (Y = 16.298 + 0.0894x - 0.0514x2; R2 = 0.95), where from the derivation of the function, we verified the highest height of the yolk (16.33 mm) at the 0.86% level of inclusion of fish by-product meal. As for the albumen height, a quadratic effect ($p < 0.05$) (Y = 0.0151 + 4.635x - 0.5521x2; R2 = 0.91) was also observed, where from the derivation of the function, we found the highest height of the albumen (9.74 mm) at the level of inclusion of 4.19% of fish by-product meal in the diets. The increasing inclusion of fish by-product meal in the diets provided an increase in the height of the yolk and albumen.

For Keener, Mcavoy, and Foegeding (2006) and Trindade, Nascimento and Furtado (2007), this increase, as well as alterations in the relationship between yolk and albumen, varies according to egg size, resulting in larger eggs, and to the progressive nutritional enrichment that birds can acquire from diets with alternative foods with deposition of nutrients in specific regions of the egg, among others variables of quality related to bird management.

In the other egg quality variables, no significant differences were detected ($p > 0.05$), where the results indicated no changes, mainly in the quality of the shell and in the Haugh unit, caused by the inclusion of fish by-product meal in feed for commercial laying hens.

In the economic analysis (Table 5), differences ($p < 0.05$) were found in feed cost, with a quadratic effect ($p < 0.05$) ($Y = 74.49 + 0.6839x - 0.3221x^2$, $R^2 = 0.75$), in which, from the derivation of the function obtained, the highest feed cost (R$ 74.85) was obtained at the 1.06% level of inclusion of fish by-product meal in the diets.

Differences ($p < 0.05$) were also observed in the cost of production, where from the derivation of the quadratic function ($p < 0.05$) ($Y = 0.218 + 0.00067x - 0.0007x^2$; $R^2 = 0.86$), the highest cost of production (R$ 0.21) was found at the level of inclusion of 0.47% of fish by-product meal in feed.

These results still demonstrate a significant reduction in feed costs and, consequently, in production costs, where the levels with higher inclusion of fish by-product meal in the diets provided greater savings and lower production costs. Rufino et al. (2015), in an economic analysis of tucumã by-product meal in laying diets, affirm that the use of agribusiness waste in feed can lead to a significant reduction in the production cost due to the substitution potential that they may have on the feed or a specific input, however, all other costs must be constant in the analysis.

Importantly, an alternative food, whether of animal or plant origin, only has a real potential of inclusion in the feed when it provides conditions of decrease in food costs, and consequently, in total costs; when it has biological value similar to or better than conventional foods and when it is highly available in the market that can supply a purchase demand for feed production. Conversely, failure to attend to any of these items may compromise the zootechnical and economic viability of applying alternative food at an experimental or industrial level.

Table 5. Economic analysis of the cost of diets containing fish by-product meal associated with the egg production of commercial laying hens.

Variables	Levels of inclusion of fish by-product meal (%)					P-value	Effect	CV, %
	0	1	2	3	4			
Feed price (R$/kg)	1.46	1.45	1.44	1.43	1.42	-	-	-
Cumulative feed cost (kg)	51.31	50.98	52.25	49.36	49.53	0.07	ns	2.94
Feed cost (R$)	74.91	73.92	75.24	70.59	70.33	0.01	Q	2.92
Egg production	361.00	375.00	377.00	402.00	404.00	0.55	ns	11.01
Production cost (R$)	0.21	0.20	0.20	0.17	0.17	0.05	Q	12.17

CV – Coefficient of variation. P-value– Coefficient of Probability. Q –Quadratic effect. ns –non-significant.

In this sense, Costa et al. (2009) also state that factors such as ease of acquisition, production and fluctuation of input prices should also be considered in deciding whether or not to use an alternative ingredient, and these help prove the economic viability of using this particular product.

Conclusion

Fish by-product meal may be used as an alternative feed in diets for commercial egg laying hens, providing improved egg production, feed conversion, egg weight, yolk: albumen ratio, reduction in feed and production costs.

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