Acta Scientiarum
http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v45i1.57534

NONRUMINANT NUTRITION

Effects of dietary fiber on performance and egg quality of laying hens at pre-laying and laying peak

Pedro Gabriel Carneiro de Andrade, Marco Antonio de Freitas Mendonça, Frank George Guimarães Cruz, João Paulo Ferreira Rufino*, Fernanda Moura Fernandes Silva and Lucas de Almeida Reis

Faculdade de Ciências Agrárias, Universidade Federal do Amazonas, Avenida General Rodrigo Octávio Jordão Ramos, 6200, 69077-000, Manaus, Amazonas, Brasil. *Author for correspondence. E-mail: joaopaulorufino@live.com

ABSTRACT. This study aimed to evaluate the effects of different levels of dietary fiber on the performance and egg quality of laying hens at pre-laying and laying peak periods. The experimental period was divided into three periods: pre-laying (16 to 19 weeks of age), the start of laying (20 to 22 weeks of age) and laying peak (23 to 28 weeks of age). The experimental design was completely randomized with treatments constituted by five levels of fiber (2.00, 2.50, 3.00, 3.50, and 4.00%) in the diets, with five replicates (pens) of six birds each, totalling 180 hens. Performance and egg quality results were evaluated by polynomial regression at 5%. Fiber levels were not influenced ($p > 0.05$) the first laying of the hens. However, levels above 2.50% of fiber provided worst ($p < 0.05$) performance results, regardless of the period evaluated. Shortly after the start of laying, higher levels of fiber also caused a linear reduction ($p < 0.05$) on egg weight and percentages of yolk and albumen, and an increase ($p < 0.05$) on eggshells. Higher fiber levels caused a linear reduction ($p < 0.05$) in the quality of the eggs, regardless of the period evaluated. It was concluded that the fiber levels did not influence the start period of the laying. Both pre-laying and start of the laying, levels above 2.5% of fiber caused a gradual worsening in performance. From the start of laying up to laying peak, levels above 2.5% of fiber also caused a gradual worsening in egg quality.

Keywords: animal nutrition; eggshell; egg weight; feed intake; poultry.

Received on January 24, 2021.
Accepted on October 5, 2021.

Introduction

Poultry production has been one of the fastest-growing agricultural sectors in recent years, especially due to improvements in its production processes, that have been adapted to meet the demand of consumer markets (Moreira, Santos, Vieira, Tavares, & Manno, 2012; Arruda et al., 2018). However, the increasing competition between humans and animals for the main grain markets (corn, soy, wheat, among others) and own increase of the productive chain, have encouraged the development of studies about nutritional requirements that can provide alternatives to the formulation of adequate diets to livestock systems, such as poultry and pigs (Boggia, Paolotti, & Castellini, 2010; He, Meng, Li, Zhang, & Ren, 2015).

It is important to point that, for a lot of time, the correct effect of fiber used in poultry diets was not clear (Cruz & Rufino, 2017), especially due to the most studies about this theme that emphasize only the negative results (Montagne, Pluske, & Hampson, 2003; Goulart, Adorian, Mombach, & Silva, 2016). However, recent studies have been presented a new perspective about this, where a correct quantification of fiber is beneficial to birds, presenting positive effects on performance, egg quality, and so on (Mohiti-Asli et al., 2012; Incharoen & Maneechote, 2013). Fiber is pointed out as the most important dietary component for gut health (Montagne et al., 2003), presents beneficial effects that may be compared to commercial prebiotics (Goulart et al., 2016).

Obeying these new concepts has been recommended the fiber inclusion in poultry diets to maintain a low energetic density and physiological functions on the digestive tract, providing control on feed intake and nutrients absorption, and its deposition on the eggs (Braz et al., 2011). This inclusion may control the nutrients intake, nutrients absorption processes, and poultry weight. In addition, the structure of fiber and its relationship with water in the lumen greatly influence convective efficiency and microbial dynamics throughout the intestine (Incharoen & Maneechote, 2013; Yokhana, Parkinson, & Frankel, 2015).

Rufino et al. (2017) and Rufino et al. (2021) reported that great variations in the fiber levels applied to poultry diets may result in both positive and negative effects, where moderate levels tend to be the better recommendation. Normally, these effects are caused by the interaction between the type and fiber content (soluble and insoluble), birds' age, and nutritional quality of inhaled non-starch polysaccharides, making fiber acts in different forms on birds' metabolism (Kalmendal, Elwinger, Holm, & Tauson, 2011; Mohiti-Asli et al., 2012; Mtei, Abdollahi, Schreurs, Girish, & Ravindran, 2019). Considering the above, this study aimed to evaluate the effects of different levels of dietary fiber on performance and egg quality of laying hens at pre-laying and laying peak periods.

Material and methods

This study was conducted in the facilities of the Poultry Sector, College of Agrarian Sciences, Federal University of Amazonas, Manaus, Amazonas State, Brazil. The experimental procedures were approved by the Ethics Committee in Use of Animals (protocol number 011/2019) of Federal University of Amazonas, Manaus, Amazonas, Brazil.

The experimental period was divided into three periods according to the hens' age: pre-laying (16 to 19 weeks of age), start of laying (20 to 22 weeks of age), and laying peak (23 to 28 weeks of age). Hissex white hens were weighed at both periods, presenting an average weight of 1.27±0.015 kg at pre-laying/start of laying, and an average weight of 1.45±0.25 kg at laying peak. The experimental design was completely randomized with treatments constituted by five levels of fiber (2.00, 2.50, 3.00, 3.50 and 4.00%) in the diets, with five replicates (pens) of six birds each, totalling 180 hens.

Hens were subjected to an adaptation period of seven days to feed and facilities. The aviary had galvanized wire cages (1.00 x 0.45 x 0.50 m), trough feeders, and nipple drinkers. A stocking density of 13.3 birds m-2 was used, with six birds per cage. Throughout the experimental period, 16 hours of light/day were provided to the birds (12 hours of natural + 4 hours of artificial), with water and feed *ad libitum*. The temperature and air relative humidity were recorded twice a day (9 and 15 hours) from a digital hygrometer positioned at the height of the cages, obtaining average results of 30.27°C and 66.34% respectively. Egg collection was also performed twice a day (9 and 15 hours). Experimental diets (Table 1) were calculated according to the requirements provided by Rostagno et al. (2017) using the software SUPERCRAC (2004). The diets were used in the three periods evaluated.

Table 1. Experimental diets composition.

Ingredients	Levels of fiber, %				
	2.00	2.50	3.00	3.50	4.00
Corn 7.88%	69.9987	68.7059	65.3095	59.7707	55.3332
Soybean meal 46%	18.202	16.8369	16.4846	15.5753	15.1284
Limestone	9.1259	9.3684	9.3805	9.2044	9.2230
Dicalcium phosphate	1.6839	1.3000	1.2764	1.5365	1.4972
Salt	0.3895	0.3188	0.3190	0.3815	0.3824
PREMIX vitaminic/mineral	0.5000	0.5000	0.5000	0.5000	0.5000
DL-Methionine 99%	0.1000	0.1000	0.1000	0.1000	0.1000
Wheat meal	0.0000	2.8700	5.6300	11.7316	16.3358
Soybean oil	0.0000	0.0000	1.0000	1.2000	1.5000
Total	100.00	100.00	100.00	100.00	100.00
Nutrients					
Metabolizable energy, kcal.kg[-1]	2,800.00	2,800.00	2,800.00	2,800.00	2,800.00
Crude Protein, %	14.5000	14.5000	14.5000	14.5000	14.5000
Calcium, %	4.0000	4.0000	4.0000	4.0000	4.0000
Available phosphorus, %	0.4000	0.3400	0.3400	0.4000	0.4000
Sodium, %	0,1500	0.1500	0.1500	0.1500	0.1500
Crude fiber, %	2.0000	2.5000	3.0000	3.5000	4.0000
Neutral detergent fiber, %	9.4700	10.3700	11.0800	12.8400	14.1600
Acid detergent fiber, %	3.3700	3.5800	3.7500	4.2000	4.0400
Total methionine, %	0.3400	0.3300	0.3300	0.3300	0.3400
Total methionine + cystine, %	0.6128	0.6000	0.6000	0.6000	0.6120
Total lysine, %	0.7060	0.6800	0.6800	0.6780	0.6830
Total threonine, %	0.5730	0.5570	0.5530	0.5470	0.5470
Total tryptophan, %	0.1620	0.1580	0.1590	0.1620	0.1650

[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, 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.

Weekly, were evaluated the hens' performance both pre-laying, the start of laying, and laying peak, where we evaluated the date of first egg (days), feed intake (g $bird^{-1}$ day^{-1}), egg production (%), feed efficiency (kg of feed used / kg of egg), feed efficiency (kg of feed used / dozen eggs), and egg mass (g). From the start of laying (from 19 weeks of age), after subsequently periods of 21 days, four eggs to each replicate were randomly selected to evaluate egg weight (g), yolk (%), albumen (%), eggshell (%), yolk height (mm), albumen height (mm), yolk color, specific gravity (g cm^{-3}), Haugh unit, and eggshell thickness (μm).

To egg quality analyses, this study used the same methodology described by Rufino et al. (2021). The eggs were stored for one hour at 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 cm^{-3} (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. To separate albumen and yolk, a manual separator was used. Each one was placed in a plastic cup and weighted in analytical balance. Eggshells were washed, dried at an oven (50ºC) 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_{unit} = 100 x log (H + 7.57 − 1.7 x W0.37), where H = albumen height (mm), and W = egg weight (g).

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

Results and discussion

It was observed that the fiber levels did not influence ($p > 0.05$) the first laying of the hens, regardless the level used. However, both at the pre-laying and from the start of laying (from 20 weeks), it was observed a linear reduction ($p < 0.05$) on feed intake from an increase in fiber levels. Consequently, other performance variables at the start of laying (up to 20 weeks) were affected, where there was a linear reduction ($p < 0.05$) on egg production and egg mass, and a linear increase ($p < 0.05$) on feed conversion (kg kg^{-1} and kg dz^{-1}). It was important to mention that these results occurred from the fiber level of 2.50% in the diets (Table 2).

Table 2. Performance of laying hens fed diets with different levels of fiber at pre-laying (16 to 19 weeks of age) and start of laying (20 to 22 weeks of age) periods.

Variables[1]	Fiber levels (%)					p-value	Effect[2]	CV[3], %
	2.00	2.50	3.00	3.50	4.00			
FL	133.40	135.40	134.60	136.40	135.20	0.88	ns	3.46
FI (16-19 wks)	70.76	83.77	77.32	77.82	73.49	0.01	Q[4]	6.87
FI (20-22 wks)	81.16	90.52	90.41	89.60	83.39	0.05	Q[5]	6.72
EP (20-22 wks)	39.63	39.01	38.02	36.42	35.55	0.03	NL[6]	3.52
FEF-KG (20-22 wks)	3.96	4.14	4.83	4.80	5.25	0.04	PL[7]	3.70
FEF-DZ (20-22 wks)	2.37	2.44	2.68	2.87	3.25	0.05	PL[8]	3.91
EM (20-22 wks)	22.03	21.93	21.12	20.41	19.84	0.05	NL[9]	3.63

[1] FL – First laying (days); FI – Feed intake (g $bird^{-1}$ day^{-1}); EP – Egg production (%); FEF-KG – Feed efficiency (kg kg^{-1}); FEF-KG – Feed efficiency (kg dz^{-1}); EM – Egg mass(g); [2] Q – Quadratic; PL – Positive Linear; NL – Negative Linear; ns – non-significant; [3] CV – Coefficient of variation; [4] $Y = -1.9807x^2 + 9.935x + 71.914$ $R^2 = 0.76$; [5] $Y = -2.2743x^2 + 14x + 70.034$ $R^2 = 0.94$; [6] $Y = -1.075x + 40.951$ $R^2 = 0.97$; [7] $Y = 0.324x + 3.624$ $R^2 = 0.92$; [8] $Y = 0.219x + 2.065$ $R^2 = 0.94$; [9] $Y = -0.59x + 22.836$ $R^2 = 0.96$.

In the performance results at the laying peak (Table 3), higher levels of fiber caused a significant increase ($p < 0.05$) in feed efficiency and egg mass. However, intermediary levels of fiber provided better ($p < 0.05$) feed intake and egg production, with a subsequent drop ($p < 0.05$) in these variables from the use of high levels of fiber.

When we analyzed the performance results obtained in this study, it was observed that the fiber did not have a significant effect at the beginning of the laying period, did not interfere with the date for the hen to start its laying. However, according to the development of the hen and it reaches the laying peak, the effect of fiber becomes increasingly significant, directly affecting its performance. In this same process, higher fiber levels in the diets tend to hurt the performance of the hens.

Rufino et al. (2021) reported a lower effect of fiber on performance and egg quality in the short-term. However, the same authors pointed a great reduction in these results when hens fed diets with a high level of fiber for the medium or long-term. According to Mohiti-Asli et al. (2012), lower rates of egg production and poor quality of eggs from hens fed diets with high fiber levels have been attributed to disorders in feed intake or low energy intake. These results also corroborated with new concepts, where moderate levels of fiber cause positive effects, but cannot be extrapolated (Mateos, Jiménez-Moreno, Serrano, & Lázaro, 2012), because may directly interfere with the nutrients used by the hens, reducing their performance.

Table 3. Performance of laying hens fed diets with different levels of fiber at the laying peak (23 to 28 weeks of age).

Variables[1]	Fiber levels (%)					p-value	Effect[2]	CV[3], %
	2.00	2.50	3.00	3.50	4.00			
FI (23-25 wks)	98.57	105.50	106.42	105.73	105.30	0.02	Q[4]	5.14
FI (25-28 wks)	86.33	87.85	91.47	91.78	94.40	0.04	PL[5]	10.54
EP (23-25 wks)	87.14	89.68	92.86	91.11	90.79	0.05	Q[6]	3.73
EP (26-28 wks)	85.87	86.35	87.93	86.03	83.65	0.03	Q[7]	4.51
FEF-KG (23-25 wks)	2.00	2.06	2.08	2.14	2.16	0.05	PL[8]	6.59
FEF-KG (26-28 wks)	1.72	1.77	1.87	1.92	2.11	0.05	PL[9]	10.92
FEF-DZ (23-25 wks)	1.08	1.09	1.15	1.24	1.24	0.04	PL[10]	6.04
FEF-DZ (26-28 wks)	1.36	1.45	1.47	1.47	1.51	0.05	PL[11]	7.22
EM (23-25 wks)	49.15	49.20	49.28	50.84	51.23	0.04	PL[12]	5.31
EM (26-28 wks)	50.14	49.52	48.90	47.91	44.72	0.01	NL[13]	7.50

[1] FL – First laying (days); FI – Feed intake (g bird^{-1} day^{-1}); EP – Egg production (%); FEF-KG – Feed efficiency (kg kg^{-1}); FEF-KG – Feed efficiency (kg dz^{-1}); EM – Egg mass(g); [2] Q – Quadratic; PL – Positive Linear; NL – Negative Linear; [3] CV – Coefficient of variation; [4] $Y = -1.1664x^2 + 8.2676x + 92.032$ $R^2 = 0.90$; [5] $Y = 2.007x + 84.345$ $R^2 = 0.95$; [6] $Y = -0.7607x^2 + 5.4373x + 83.372$ $R^2 = 0.88$; [7] $Y = -0.6571x^2 + 4.2669x + 81.794$ $R^2 = 0.88$; [8] $Y = 0.04x + 1.968$ $R^2 = 0.97$; [9] $Y = 0.093x + 1.599$ $R^2 = 0.93$; [10] $Y = 0.047x + 1.019$ $R^2 = 0.91$; [11] $Y = 0.032x + 1.356$ $R^2 = 0.82$; [12] $Y = 0.58x + 48.20$ $R^2 = 0.82$; [13] $Y = -1.245x + 51.973$ $R^2 = 0.85$.

Traditionally, studies about fiber and its sources in poultry diets consider fiber as a diet diluent (Rougière & Carré, 2010), with a negative effect on performance and egg quality (Mateos et al., 2012). Front this, Van Soest (1994) and Rufino et al. (2017) affirmed that the increase in fiber levels tends to increase the gut viscosity and decrease the contact area of enzymes with food, causing interference in the passage rate and decreasing the use of nutrients according to the hens' fitness.

The fiber acts as a physical barrier, preventing that the enzymes have access to the nutritional content of vegetable cells, reducing digestion, and increasing the hens' gastrointestinal tract size (Kalmendal et al., 2011; Mateos et al., 2012). A great increase of fiber level or its action period may raise the viscosity in the gut, decreasing the contact area of enzymes, interfering the passage rate, resulting in lower use of the nutrients and worst performance (Van Soest, 1994). An increase in dietary fiber might also increase the production of saliva, gastric juices, and pepsin. However, these effects also depend on the gastrointestinal tract analyzed area, because the duodenum performs a different function from the jejunum and the ileum (Incharoen & Maneechote, 2013).

It is important to mention that the fiber is the most important dietary component for gut health, helping the beneficial and pathogenic microbial balance, and presenting benefits compared to commercial prebiotics (Montagne et al., 2003), implies yet another possible positive effect caused by its moderate inclusion in poultry diets (Goulart et al., 2016). Some studies reported that the use of feedstuffs with a large amount of fiber tends to increase the gut viscosity due to the fiber fraction being rich in soluble non-starch polysaccharides, such as arabinoxylans, which may cause a general inhibition of food digestion, affecting the digestibility of carbohydrates, fats and proteins, which directly affects the performance and egg quality (Freitas et al., 2014; Rufino et al., 2017).

In the results of egg weight and main percentages of egg structures (Table 4), it was observed that, shortly after the start of laying, higher levels of fiber in the diets caused a linear reduction ($p <0.05$) in egg weight and percentages of yolk and albumen. However, in percentages of the eggshell, it was observed a linear increase ($p <0.05$). After 22 weeks, higher levels of fiber in the diets caused a significant reduction ($p <0.05$) in the percentages of eggshells.

Higher fiber levels in the diets caused a linear reduction ($p <0.05$) on the quality of the eggs (Table 5), regardless of the period evaluated. This reduction in egg quality was evidenced especially due to the negative linear results ($p <0.05$) of yolk and albumen heights, specific gravity, Haugh unit, and eggshell thickness, besides the positive linear effect ($p <0.05$) observed on yolk diameter.

When we analyzed the results of egg quality it was observed that, as the increase of birds' age and the proximity of the laying peak, high fiber levels caused a significant negative effect on the quality of the eggs. It was also observed in the results of this study that hens fed diets with low and moderate levels of fiber, up to 2.50% of fiber, produced eggs with better internal and external quality. Physiologically, high levels of fiber tend to change all gut functioning. And how the absorption of poultry diets nutrients directly depending on mechanisms of the gut mucosa, where the integrity of epithelial cells and the action of digestive enzymes in the lumen are essential for nutrients to be well used (Jiménez-Moreno, Frikha, Coca-Sinova, García & Mateos, 2013), the presence of blockages in these processes can cause significant losses on performance and blocking the nutrients to be deposited in the eggs (Rufino et al., 2021).

Table 4. Egg weight and percentages of albumen, yolk, and eggshell of eggs from laying hens fed diets with different levels of fiber at the start of laying (20 to 22 weeks of age) and laying peak (23 to 28 weeks of age).

Variables[1]	Fiber levels (%)					p-value	Effect[2]	CV[3], %
	2.00	2.50	3.00	3.50	4.00			
EW (19-22 wks)	57.74	55.90	55.74	55.38	53.84	0.04	NL[4]	3.21
EW (23-25 wks)	56.54	56.18	55.98	54.85	53.01	0.05	NL[5]	3.83
EW (26-28 wks)	57.32	57.01	56.91	55.67	53.39	0.01	NL[6]	4.94
ALB (19-22 wks)	65.17	64.35	62.81	62.42	61.60	0.04	NL[7]	5.18
ALB (23-25 wks)	58.84	59.51	62.39	61.95	59.08	0.03	Q[8]	5.84
ALB (26-28 wks)	60.88	61.68	63.72	61.68	61.48	0.05	Q[9]	4.28
YLK (19-22 wks)	26.53	26.24	25.85	25.76	25.53	0.02	NL[10]	5.63
YLK (23-25 wks)	7.66	26.25	26.40	25.94	25.89	0.05	NL[11]	3.67
YLK (26-28 wks)	23.77	24.14	24.35	23.51	23.37	0.02	Q[12]	4.78
ESH (19-22 wks)	9.64	9.73	10.60	11.16	11.50	0.04	PL[13]	5.61
ESH (23-25 wks)	10.43	10.31	10.21	10.17	10.04	0.05	NL[14]	4.18
ESH (26-28 wks)	10.48	10.49	10.86	10.74	10.58	0.05	Q[15]	4.63

[1] EW – Egg weight (g); ALB – albumen (%); YLK – yolk (%); ESH – eggshell (%); [2] Q – Quadratic; PL – Positive Linear; NL – Negative Linear; [3] CV – Coefficient of variation; [4] $Y = -0.832x + 58.216$ $R^2 = 0.89$; [5] $Y = -0.839x + 57.829$ $R^2 = 0.85$; [6] $Y = -0.92x + 58.82$ $R^2 = 0.80$; [7] $Y = -0.907x + 65.991$ $R^2 = 0.96$; [8] $Y = -0.7429x^2 + 4.7491x + 55.278$ $R^2 = 0.75$; [9] $Y = -0.4343x^2 + 2.7257x + 58.488$ $R^2 = 0.60$; [10] $Y = -0.248x + 26.726$ $R^2 = 0.96$; [11] $Y = -0.385x + 27.583$ $R^2 = 0.71$; [12] $Y = -0.1479x^2 + 0.9441x + 23.222$ $R^2 = 0.74$; [13] $Y = 0.515x + 8.981$ $R^2 = 0.95$; [14] $Y = -0.092x + 10.508$ $R^2 = 0.97$; [15] $Y = -0.0593x^2 + 0.4007x + 10.28$ $R^2 = 0.63$.

Table 5. Internal and external quality of eggs from laying hens fed diets with different levels of fiber at the start of laying (20 to 22 weeks of age) and laying peak (23 to 28 weeks of age).

Variables[1]	Fiber levels (%)					p-value	Effect[2]	CV[3], %
	2.00	2.50	3.00	3.50	4.00			
YH (20-22 wks)	15.77	15.56	15.21	15.09	15.07	0.02	NL[4]	2.44
YH (23-25 wks)	13.04	14.19	14.55	14.49	13.73	0.01	Q[5]	7.73
YH (26-28 wks)	15.51	15.49	15.40	15.34	14.69	0.01	NL[6]	2.52
AH (20-22 wks)	10.16	10.74	10.03	10.38	10.14	0.34	ns	5.57
AH (23-25 wks)	9.03	8.89	8.85	8.15	6.93	0.01	NL[7]	8.27
AH (26-28 wks)	9.88	9.86	9.60	9.37	9.02	0.05	NL[8]	5.48
YD (20-22 wks)	38.45	39.50	39.83	39.90	40.09	0.02	PL[9]	2.02
YD (23-25 wks)	39.82	41.13	41.17	41.44	41.82	0.02	PL[10]	3.53
YD (26-28 wks)	38.45	39.50	39.83	39.90	40.09	0.02	PL[11]	2.02
YC (20-22 wks)	5.45	5.10	4.70	4.75	4.32	0.01	NL[12]	9.18
YC (23-25 wks)	5.75	5.25	5.15	5.10	4.30	0.01	NL[13]	6.67
YC (26-28 wks	4.10	3.95	3.85	3.80	3.70	0.04	NL[14]	.20
SG (20-22 wks)	1,090.25	1,088.00	1,086.50	1,086.00	1,083.00	0.02	NL[15]	0.29
SG (23-25 wks)	1,089.50	1,089.50	1,089.00	1,088.50	1,087.75	0.05	NL[16]	0.37
SG (26-28 wks)	1,090.50	1,089.00	1,089.00	1,088.50	1,087.25	0.03	NL[17]	0.58
HU (20-22 wks)	91.30	89.37	89.32	88.90	87.40	0.03	NL[18]	9.82
HU (23-25 wks)	90.27	89.93	89.74	88.72	87.10	0.04	NL[19]	9.93
HU (26-28 wks)	90.92	90.61	90.55	89.34	87.12	0.03	NL[20]	9.89
ET (20-22 wks)	0.38	0.29	0.29	0.28	0.28	0.01	NL[21]	6.49
ET (23-25 wks)	0.28	0.27	0.27	0.26	0.26	0.05	NL[22]	7.15
ET (26-28 wks)	0.29	0.29	0.29	0.28	0.27	0.05	NL[23]	5.76

[1] YH – Yolk height (mm); AH – Albumen height (mm); YH – Yolk diameter (mm); YH – Yolk color; Specific gravity ($g.mL^{-3}$); HU – Haugh unit; ET - eggshell thickness (μm);[2] Q – Quadratic; PL – Positive Linear; NL – Negative Linear; ns – non-significant; [3] CV – Coefficient of variation; [4] $Y = -0.187x + 15.901$ $R^2 = 0.90$; [5] $Y = -0.3029x^2 + 1.9851x + 11.376$ $R^2 = 0.99$; [6] $Y = -0.179x + 15.823$ $R^2 = 0.69$; [7] $Y = -0.494x + 9.852$ $R^2 = 0.79$; [8] $Y = -0.221x + 10.209$ $R^2 = 0.93$; [9] $Y = 0.368x + 38.45$ $R^2 = 0.79$; [10] $Y = 0.431x + 39.783$ $R^2 = 0.81$; [11] $Y = 0.368x + 38.45$ $R^2 = 0.79$; [12] $Y = -0.261x + 5.647$ $R^2 = 0.92$; [13] $Y = -0.305x + 6.025$ $R^2 = 0.85$; [14] $Y = -0.095x + 4.165$ $R^2 = 0.97$; [15] $Y = -1.65x + 1091.7$ $R^2 = 0.95$; [16] $Y = -0.45x + 1090.2$ $R^2 = 0.92$; [17] $Y = -0.7x + 1091$ $R^2 = 0.89$; [18] $Y = -0.827x + 91.739$ $R^2 = 0.88$; [19] $Y = -0.755x + 91.417$ $R^2 = 0.86$; [20] $Y = -0.887x + 92.369$ $R^2 = 0.80$; [21] $Y = -0.021x + 0.367$ $R^2 = 0.80$; [22] $Y = -0.005x + 0.283$ $R^2 = 0.89$; [23] $Y = -0.005x + 0.299$ $R^2 = 0.78$.

According to Yokhana et al. (2015), high levels of fiber normally cause disturbances in the energy metabolism of the hen, which are even more evident in young birds where the physiology is more sensitive and tends to present a rapid response. Already Laudadio, Ceci, Lastella and Tufarelli (2014) reported that the use of high levels of fiber sources may increase the feed intake of laying hens, but tend to cause a bad effect on feed conversion and egg quality.

Conclusion

It was concluded that the fiber levels did not influenced the start period of the laying. Both pre-laying and start of the laying, levels above 2.5% of fiber caused a gradual worsening on performance. From start of laying up to laying peak, levels above 2.5% of fiber also caused a gradual worsening on egg quality.

References

Arruda, J. C. B., Fonseca, L. A. B., Pinto, L. C. P., Pinheiro, H. C. O., Monteiro, B. T. O., Manno, M. C., Lima, K. R. S., & Lima, A. R. (2018). Açaí seed bran in the feed of slow-growth broilers. *Acta Amazonica, 48*(4), 298-303. DOI: https://doi.org/10.1590/1809-4392201703994

Boggia, A., Paolotti, L., & Castellini, C. (2010). Environmental impact evaluation of conventional, organic and organic-plus poultry production systems using life cycle assessment. *World's Poultry Science Journal, 66*(1), 95-114. DOI: https://doi.org/10.1017/S0043933910000103

Braz, N. M., Freitas, E. R., Bezerra, R. M., Cruz, C. E. B., Farias, N. N. P., Silva, N. M., Sá, N. L., & Xavier, R. P. S. (2011). Fiber in growth ration and its effects on performance of laying hens during the growing and laying phases. *Brazilian Journal of Animal Science, 40*(12), 2744-2753. DOI: https://doi.org/10.1590/S1516-35982011001200019

Cruz, F. G. G., & Rufino, J. P. F. (2017). *Formulação e fabricação de rações (aves, suínos e peixes)*. Manaus, AM: EDUA.

Freitas, E. R., Braz, N. M., Watanabe, P. H., Cruz, C. E. B., Nascimento, G. A. J., & Bezerra, R. M. (2014). Fiber level for laying hens during the growing phase. *Ciência e Agrotecnologia*, *38*(2), 188-198. DOI: https://doi.org/10.1590/S1413-70542014000200010

Goulart, F. R., Adorian, T. J., Mombach, P. I., & Silva, L. P. (2016). Importância da fibra alimentar na nutrição de animais não ruminantes. *Revista de Ciência e Inovação, 1*(1), 141-154. DOI: https://doi.org/10.26669/2448-4091104

He, L. W., Meng, Q. X., Li, D. Y., Zhang, Y. W., & Ren, L. P. (2015). Influence of feeding alternative fiber sources on the gastrointestinal fermentation, digestive enzyme activities and mucosa morphology of growing Greylag geese. *Poultry Science, 94*(10), 2464-2471. DOI: https://doi.org/10.3382/ps/pev237

Incharoen, T., & Maneechote, P. (2013). The effects of dietary whole rice hull as insoluble fiber on the flock uniformity of pullets and on the egg performance and intestinal mucosa of laying hens. *American Journal of Agricultural and Biological Sciences, 8*(4), 323-329. DOI: https://doi.org/10.3844/ajabssp.2013.323.329

Jiménez-Moreno, E., Frikha, M., Coca-Sinova, A., García, J., & Mateos, G.G. (2013). Oat hulls and sugar beet pulp for broiler diets: 1. Effects on growth performance and nutrient digestibility. *Animal Feed Science and Technology, 182*(1-4), 33-43. DOI: https://doi.org/10.1016/j.anifeedsci.2013.03.011

Kalmendal, R., Elwinger, K., Holm, L., & Tauson, R. (2011). High-fibre sunflower cake affects small intestinal digestion and health in broiler chickens. *British Poultry Science, 52*(1), 86-96. DOI: https://doi.org/10.1080/00071668.2010.547843

Laudadio, V., Ceci, E., Lastella, N. M. B., & Tufarelli, V. (2014). Effect of feeding low-fiber fraction of air-classified sunflower (*Helianthus annus* L.) meal on laying hen productive performance and egg yolk cholesterol. *Poultry Science, 93*(11), 2864-2869. DOI: https://doi.org/10.3382/ps.2014-04204

Mateos, G. G., Jiménez-Moreno, E., Serrano, M. P., & Lázaro, R. P. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. *Journal of Applied Poultry Research, 21*(1), 156-174. DOI: https://doi.org/10.3382/japr.2011-00477

Mohiti-Asli, M., Shivazad, M., Zaghari, M., Rezaian, M., Aminzadeh, S., & Mateos, G.G. (2012). Effects of feeding regimen, fiber inclusion, and crude protein content of the diet on performance and egg quality and hatchability of eggs of broiler breeder hens. *Poultry Science, 91*(12), 3097-3106. DOI: https://doi.org/10.3382/ps.2012-02282

Montagne, L., Pluske, J., & Hampson, D. (2003). A review of interactions between dietary fibre and the intestinal mucosa, and their consequences on digestive health in young non-ruminant animals. *Animal Feed Science and Technology, 108*(1-4), 95-117. DOI: https://doi.org/10.1016/S0377-8401(03)00163-9

Moreira, A. S., Santos, M. S. V., Vieira, S. S., Tavares, F. B., & Manno, M. C. (2012). Performance of broiler chickens fed diets containing different levels of metabolizable energy. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 64*(4), 1009-1016. DOI: https://doi.org/10.1590/S0102-09352012000400030

Mtei, A. W., Abdollahi, M. R., Schreurs, N., Girish, C. K., & Ravindran, V. (2019). Dietary inclusion of fibrous ingredients and bird type influence apparent ileal digestibility of nutrients and energy utilization. *Poultry Science, 98*(12), 6702-6712. DOI: https://doi.org/10.3382/ps/pez383

Rostagno, H. S., Albino, L. F. T., Hannas, M. I., Donzele, J. L., Sakomura, N. K., Costa, F. G. P., ... Brito, C. O. (2017). *Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais*. Viçosa, MG: Editora da Universidade Federal de Viçosa.

Rougière, N., & Carré, B. (2010). Comparison of gastrointestinal transit times between chickens from D+ and D- genetic lines selected for divergent digestion efficiency. *Animal, 4*(11), 1861-1872. DOI: https://doi.org/10.1017/S1751731110001266

Rufino, J. P. F., Cruz, F. G. G., Oliveira Filho, P. A., Melo, R. D., Feijó, J. C., & Melo, L. D. (2017). Fibra alimentar em dietas para aves – uma revisão. *Revista Científica de Avicultura e Suinocultura, 3*(2), 33-42.

Rufino, J. P. F., Cruz, F. G. G., Brasil, R. J. M., Oliveira Filho, P. A., Melo, R. D., & Feijo, J. C. (2021). Relationship between the level and the action period of fiber in diets to laying hens. *Acta Scientiarum. Animal Sciences, 43*(1), e49033. DOI: https://doi.org/10.4025/actascianimsci.v43i1.49033

Supercrac. (2004). *Ração de custo mínimo. Versão 1.02, para Windows*. [S.I]: TD Software.

Van Soest, P. J. (1994). *Nutritional ecology of the ruminant*. New York, NY: Cornell University Press.

Yokhana, J. S., Parkinson, G., & Frankel, T. L. (2015). Effect of insoluble fiber supplementation applied at different ages on digestive organ weight and digestive enzymes of layer-strain poultry. *Poultry Science, 95*(3), 550-559. DOI: https://doi.org/10.3382/ps/pev336