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Fiber levels in laying quail diets

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Abstract: The objective of this work was to determine the effect of inclusion levels of dietary fiber in the Japanese quail diets. 480 Japanese quail were distributed in a completely randomized design, with 5 treatments and 12 replicates composed of 8 birds each. The treatments were constituted by five increasing levels of fiber in the diet: 2.78; 3.08; 3.38; 3.68; 3.98%. The parameters of productive performance, water consumption, egg quality, total lipids in the egg, excreta humidity, weight of digestive organs and intestinal morphology were evaluated. There was no significant effect of the use of different fiber levels on feed intake, egg production, viability, live weight, relative and absolute weight of gizzard, small intestine and cecum, and in excreta moisture of Japanese quais. Higher dietary fiber levels resulted in improvements in feed conversion per mass and per dozen eggs and higher water consumption. There was no significant difference for egg quality, except fot the color of the yolk where it was observed higher pigmentation of this structure with higher levels of fiber inclusion, and the lipid concentration in the buds was influenced in a quadratic manner. The inclusion of fiber promoted improvement in the villi of the duodenum and cecum.

Key words: bone quality, excreta moisture, intestinal morphology, lipid in the yolk, water consumption.

INTRODUCTION

Fiber is the fraction of the feed that is not digestible by the endogenous enzymes of animals, but rather by the action of enzymes from the gastrointestinal microbiota (Tungland & Meyer 2002), its chemical composition ranges considerably depending on its origin (Teixeira 1995), content of cellulose, hemicellulose, pectin and lignin (Castro Júnior et al. 2005). The lignin present in the fibers is one of the main responsible for the great variation of its digestibility which is not apparently degraded by birds and pigs, therefore, having in these species the digestibility of non-starch polysaccharides, reduced mainly due to the covalent bonds maintained with both cellulose and hemicellulose, besides not being digested by microorganisms present in their intestines (Johnston et al. 2003).

In general, little importance has been attributed to fiber in bird nutrition, there not being minimal recommendation with for fiber content in the strain handbooks or tables of research institutions (Leite et al. 2018). On the other hand, dietary fiber supplementation promotes beneficial effects on the microbial profile of the gastrointestinal tract (GIT) in broiler chickens (Sabour et al. 2018), therefore, the investigation of fiber levels in monogastric diets and their influence over digestive physiology, are generating more and more interests (Castro Júnior et al. 2005).

Fiber in monogastric diets is mainly used in the cecum and is carried out by a diverse microbial population (Walugembe et al 2015), the degradation of which generates formation of volatile fatty acids (VFAs) that are easily absorbed by the intestine, improving the quality of its mucosa (Castro Júnior et al. 2005). Quails are able to take advantage of diets with higher fiber contents, because according to Duarte et al. (2013), these birds have a larger relative size of the cecum compared to the chickens besides a morphologically more developed mucosa.

According to F.L. Mourinho (unpublished data), with the use of the fiber, changes in intestinal transit time, mucosal structure and greater intestinal viscosity may occur, which promote a better interaction of the digesta with the microbiota, thus improving the nutrient absorption. Roque et al. (2006) cite that fiber aids in gastrointestinal motility, stool consistency and diarrhea reduction by increased water absorption and decrease of pH of the intestinal environment.

According to A.H.S. Clemente (unpublished data) fiber consumption can negatively and positively affect the physicochemical properties of the digestive processes. Negatively, when feeds contain higher levels of soluble fibers, an increase in intestinal viscosity and gel formation may occur, which sticks to the digesta particles, inhibiting the acting of the enzymes leading to a decreased nutrient utilization, positively, when the insoluble fraction of the fiber remains for a longer time in the gizzard, promoting greater fractionation of the feed and leading to a greater acting of the digestive enzymes in the small intestine, thus improving digestion. The level of fiber, whether very high or very low, will affect digestion and nutrient absorption (Li et al. 2018).

In practice, the response for inclusion of dietary fiber depends on a number of factors, such as: housing system (cages or bed), physical form of feed (mashed or pelleted), composition of the basal diet (crude fiber level and dietary lipids) and health status of the stock (biosafety, incidence of diseases and levels of pathogens in the gastrointestinal tract). The fiber source affects the rate of passage and this effect is influenced by the ability of the different components of the fiber to absorb and retain water, altering in some cases the water consumption by the birds. Several factors may influence water consumption by birds, such as the physical form of the feed, the presence of oil, sodium and crude protein levels in the diet and also fiber levels (Patrick & Ferrise 1962), directly affecting the moisture content of birds' excreta.

According to Mateos et al. (2012) inclusion of up to 3% of an insoluble fiber source is essential in chick diets, since it is provided for these simple diets (composed of soybean meal and corn) with a high protein content, and this inclusion would improve the physicochemical properties of the digesta, such as differences in digestive viscosity, ion exchange and fermentation capacity, and volume effect inside the GIT.

The fiber level required for optimal performance is not known and depends on the fiber source considered, as well as on the age of the bird and the characteristics of the components of the fibers studied (Mateos et al. 2012). Therefore, the objective of this work was to determine the best levels of inclusion of dietary fiber capable of influencing the performance, water consumption, egg quality, size of the organs of the gastrointestinal tract, intestinal villi and moisture of the excreta of Japanese quails

MATERIALS AND METHODS

This work was approved by Ceua/IZ, UFRRJ, protocol number: 23083.000398/2017-63.

The experiment was carried out in the experimental shed adapted for the quails of the

Poultry Sector of the Federal Rural University of Rio de Janeiro (UFRRJ), located in Seropédica - RJ, during the months of November 2016 to May 2017, amounting to six cycles of 28 days to be evaluated.

Four hundred and forty-eight Japanese quails were housed in pyramidal type cage batteries, containing trough-type feeder, nipple-type drinker and egg collectors. The birds were distributed in a completely randomized design, with 5 treatments and 12 replications composed of 8 birds each. The total time of the experiment was divided into six periods of 28 days each. The birds remained for 15 days in the adaptation phase to the experimental diets and when they were 39 weeks old; the data collection was started. A light program with 17 hours of daily light was adopted throughout the experimental period.

The treatments were constituted by five growing levels of fiber in the diet: 2.78; 3.08; 3.38; 3.68; 3.98% (Table I). The experimental diets were formulated to meet nutritional requirements for Japanese quails in the laying period according to Rostagno et al. (2011). The addition of fiber was done in place of the equivalent in weight of inert material (kaolin), by adjusting the percent compositions of the experimental diet in order to maintain the diets isoenergetic and isoprotic in all the treatments (Table I). The addition of fiber was done by means of a dietary fiber additive (OptiCell® C5), which was provided by BIOSEN AGRO INDUSTRIAL LTDA. The product is a synergistic combination of fermentable and non-fermentable dietary fibers produced from fresh wood selected for use in animal feeding with ultrafine particles undergoing a high temperature treatment which ensures safety in the use for animal feeding of the product. The dietary fiber concentrate used in animal feeding presents 60% crude fiber, 85% total dietary fiber and 30% lignin.

The parameters of productive performance, water consumption, egg quality, total lipids in the egg, excreta moisture, organ analysis in relation to body weight (gizzard, small intestine and cecum) and intestinal morphology were evaluated.

In the productive performance, the feed intake (g/bird/day) calculated at the end of each experimental period of 28 days, was measured by the difference between the feed provided and the orts in the buckets and feeders. The total of consumed feed was divided by the number of quails and the number of days evaluated. In the event of death, the feed from the feeder was weighed for the calculation of the corrected feed intake. Egg yield in percentage was performed based on the daily eggs yield in each treatment/replication, obtaining the means of each period. The average egg weight was obtained on the last two days of each cycle, considering all the eggs produced by treatment /replication on the day. For feed conversion per dozen of eggs produced (kg/dz), the total feed intake (kg) in the period, divided by the sum of the total egg yield in dozens for each treatment per replication in the equivalent period and feed conversion per mass of eggs (kg/kg) was considered, the division between the total feed consumption (kg) of the treatments per replications in the periods, divided by the egg mass produced (kg) of the equivalent period, was carried out**.** Daily, water consumption was measured so that in the morning the water was weighted for the supply of 1,000 grams of water for each replication in drinkers adapted from pet bottles with nipple-type beaks coupled to the cages. On the following day, the remnant of supplied water was weighed and later the drinkers were completed with a weight equivalent to 1,000 grams of water, this procedure was carried out throughout the experiment and at the end of each period the average consumption was

Table I. Formulation and Nutritional Composition of the Experimental Diets.

	Levels of Crude Fiber (%)				
INGREDIENTS (%)	**2,78**	**3,08**	**3,38**	**3,68**	**3,98**
Corn	52.500	52.500	52.500	52.500	52.500
Soybean meal	33.180	33.180	33.180	33.180	33.180
Limestone	6.750	6.750	6.750	6.750	6.750
Soybean oil	2.880	2.880	2.880	2.880	2.880
DicalciumPhosphate	1.090	1.090	1.090	1.090	1.090
Dl-methionine	0.350	0.350	0.350	0.350	0.350
Common Salt	0.320	0.320	0.320	0.320	0.320
Vitamin salt[1]	0.100	0.100	0.100	0.100	0.100
Mineral Salt[2]	0.100	0.100	0.100	0.100	0.100
L-lysine	0.160	0.160	0.160	0.160	0.160
L-threonine	0.010	0.010	0.010	0.010	0.010
Choline chloride 60%	0.035	0.035	0.035	0.035	0.035
Kaolin	2.500	2.000	1.500	1.000	0.500
OptiCell® C5	0.000	0.500	1.000	1.500	2.000
Total	100	100	100	100	100
CALCULATED NUTRITIONAL NUTROMPOSITION					
Metabolizable Energy (Mcal/kg)	2800	2800	2800	2800	2800
Crude Protein (%)	19.5	19.5	19.5	19.5	19.5
Crude Fiber (%)					
Calcium (ca%)	2.9090	2.9090	2.9090	2.9090	2.9090
Available Phosphorus (%)	0.3075	0.3075	0.3075	0.3075	0.3075
Chlorine (%)	0.2400	0.2400	0.2400	0.2400	0.2400
Digestible Lysine (%)	1.0807	1.0807	1.0807	1.0807	1.0807
Total Lysine(%)	1.1740	1.1740	1.1740	1.1740	1.1740
Digestible Met + cystine (%)	0.8767	0.8767	0.8767	0.8767	0.8767
Total Methionine + cystine (%)	0.9510	0.9510	0.9510	0.9510	0.9510
Digestible Methionine (%)	0.6107	0.6107	0.6107	0.6107	0.6107
Total Methionine (%)	0.6361	0.6361	0.6361	0.6361	0.6361
Digestible threonine (%)	0.6723	0.6723	0.6723	0.6723	0.6723
Total Threonine (%)	0.7685	0.7685	0.7685	0.7685	0.7685
Digestible Tryptophan (%)	0.2187	0.2187	0.2187	0.2187	0.2187
Total tryptophan (%)	0.2405	0.2405	0.2405	0.2405	0.2405

[1]Vitamin A (min) 7.500.000 UI/Kg; vitamin D3 (min) 2.500.000 II/Kg; vitamin E (min) 1.200 mg/Kg; vitamin K3 (min) 1.200 mg/Kg; thiamine (min) 1.500 mg/Kg; riboflavin (min) 5.500 mg/Kg; pyridoxine (min) 2000 mg/Kg; vitamin B12 (min) 12.000 mcg/Kg; niacin 35 g/kg; calcium pantothenate (min) 10 g/Kg; biotin (min) 67 mg/Kg; [2]Iron) 60 g/Kg; copper (min) 13 g/Kg; manganese (min) 120 g/Kg; zinc (min) 100 g/Kg; iodine (min) 2.500 mg/Kg; selenium (min) 500 mg/Kg.

calculated. In the productive performance, the feed intake (g/bird/day) calculated at the end of each experimental 28-day period by the difference between the feed provided and the orts in the buckets and feeders, was measured. The total of consumed feed was divided by the number of quails and the number of days evaluated. In the event of death, the feed of the feeder was weighed for the calculation of the corrected feed intake. Egg yield in percentage was performed based on the daily production of eggs in each treatment/replication, obtaining the means of each period. The average weight of the eggs was obtained during the last two days of each cycle, considering all the eggs produced by treatment/replication on the day.

Egg quality analyses were performed at the end of each 28-day period in the Laboratory of Analysis of Animal Products of the Animal Science Institute of UFRRJ. For each evaluation, three eggs per replication (36 eggs per treatment) were used for two consecutive days, thus totaling 360 units evaluated in each analysis.

In order to calculate the Haugh Unit, the weight of the egg before the breakage was obtained on digital scale with an accuracy of 0.01 g, and with the aid of a tripod micrometer, the height of the dense albumen was measured, using these values in the following equation: UH = 100log (H +7.57 - 1.7W0.37), where H = height of the dense albumen (mm) and W = weight of the egg (g). The yolk index was calculated through the ratio between height and diameter of this structure. The yolk and albumen were carefully separated and the height of the yolk measured with the aid of a tripod micrometer and its diameter measured with a digital caliper. For the percentage of the components of the eggs, they were broken and had their gems separated and weighed on a digital scale with a precision of 0.01 g, the shells washed to remove albumen residues and oven-dried at 105°C for 2 hours, and later also weighted. From the subtraction of the weight of the yolk and the shell from the total weight of the egg, the weight of the albumen was obtained. The shell thickness was measured after drying the samples by using a digital pressure micrometer. The shell thickness values were obtained from the mean of two fragments from the equatorial zone of the shell. In the analytical laboratory of Food and Beverage (IT-UFRRJ), the total of the yolk lipids was determined from two egg yolks per replication of eggs of the last cycle of the experimental period, amounting to 24 yolks analyzed per treatment. The determination of total lipids was carried out through the methodology proposed by Gerber (1935), where the samples are mixed in the butyrometer with 10 mL of sulfuric acid and 1 mL of isoamyl alcohol and then centrifuged for 5 minutes at 1000-1200 rpm and subsequently kept in water bath for 5 minutes.

At the end of the last experimental period, the excreta were collected for four consecutive days in plastic bags, duly identified by the total excreta collection method (Sibbald & Slinger 1963) and later sent to the Bromatology Laboratory of the Department of Animal Nutrition (UFRRJ), where they were weighed, homogenized and dried in a forced ventilation oven at 55°C for 72 hours. Next, the samples were then ground in a knife-type mill and packed in flasks to determine the moisture content of the excreta.

On the last experimental day, euthanasia of 1 bird/replication by cervical displacement was performed in a total of 60 quails. By using a 0.01g precision scale, the weight of the dead bird was measured and the weight of the gizzard, small intestine and ceca were measured and the data expressed in absolute (in grams) and relative (in percentage in comparison to the body weight of the bird) weights. The intestines were used for the carrying out of the morphometric parameters, according to the methodology described by Liu (unpublished data), where a sample of the median portion of the duodenum and cecum was used for evaluation of the height of the villi and depth of the crypts, only histological slides with visible set and defined epithelium were measured and 5 villi were selected per histological section in 10 different sections, with a minimum distance of 100 μm between them, in a total of 50 villi per bird. The proportion villus height/crypt depth was calculated and expressed by the ratio between height of a villi and the depth of the corresponding crypt of this same villus in the segments.

The results obtained were submitted to analysis of variance and, later, the effects of the different dietary fiber levels estimated by means of analysis of the variables by the regression models at the significance level of 5%, according to the best adjustment obtained for each variable, based on the highest value of coefficient of determination for the choice of the model by the BioEstat program.

RESULTS AND DISCUSSION

There was no significant effect (p> 0.05) from the use of different fiber levels over feed consumption, egg yield and viability of Japanese quails (Table II). Hartini & Choct (2010) found a reduction in the mortality of layers fed higher fiber contents, a fact not observed in the present study. Duarte et al. (2013) evaluating the inclusion of soybean hulls in the laying quail diet, raising the crude fiber level from 2.788% to 8.683%, also did not find significant differences for feed intake and percentage of egg yield, but different from present study, they found no significant differences for feed conversion per mass and per dozen eggs produced.

In the present study, higher dietary fiber levels resulted in improvements in feed conversion (p <0.05). These results are not in agreement with the findings by Freitas et al. (2014), who investigated the effect of different levels of crude fiber in the diet (3.14, 3.5, 3.92, 4.38%) in light and semi-heavy pullets in growing phase found a worsening in the feed

Table II. **Feed consumption (g), water consumption (mL), percentage of egg yield (% yield), feed conversion per dozen eggs (CA/dz), feed conversion per egg mass (CA/mass) and viability (%) of Japanese quails fed diets containing different levels of crude fiber.**

Levels of Crude Fiber (%)	Feed intake	Water consumption	% Yield	CA/dz	CA/mass	Viability
2,78	26.548	69.1773	86.77	0.38	2.69	98.00
3.08	25.488	69.3482	83.99	0.37	2.70	98.59
3.38	26.019	71.1469	86.68	0.36	2.61	98.79
3.68	25.581	70.9586	87.00	0.36	2.59	99.01
3.98	25.455	76.9034	88.90	0.35	2.48	98.59
REGRESSION	NS	L*	NS	L**	L***	NS
CV (%)	4.74	12.97	7.23	8.46	8.24	1.94

NS = non-significant for regression analysis (p>0.05); L* = Linear Regression; Equation: Y = 68.6827 + 3.5303 X; p < 0.0001; L = Linear Regression; Equation: Y = 0.3745 - 0.0128 X; p = 0.0142; L*** = Linear Regression; Equation: Y = 2.7012 - 0.0128 X; p = 0.0036; CV = coefficient of variation.**

conversion of the pullets regardless of the strain tested for the highest level of fiber inclusion tested. The increased inclusion of fiber can lead to a reduction in the pH of the gizzard, favoring the acidic digestion of the feed (Mateos et al. 2012), besides influencing the diversity of the composition of the microbiota, making its more diverse and with greater possibility of fighting the pathogenic microbiota, making it difficult its installation and production of toxins that degrade the mucosa and increase nutritional and energy expenditure for intestinal repair (Li et al. 2018). Water consumption was influenced in a linear way ($p < 0.05$) by the inclusion of fiber in the diet of the quails. One of the most important factors influencing water intake by birds is the ingestion of feed, for being capable of altering the whole balance, interfering in the metabolic water, that is, water coming from intermediate metabolism (Macari 1995), Donkoh et al. (2002) found that with increased inclusion of fiber for broiler chickens, water consumption was less, however, it also reduced feed consumption opposite to that observed in the present experiment, in which as the inclusion of fiber was increased, higher consumption of water occurred, not alternating feed consumption. Despite the increase in fiber level not having altered feed intake, feed conversion improved, for the higher yield of mass and dozen eggs, even without increasing the amount of feed consumed. In contrast, the quails increased water intake to meet the requirements for egg formation, since according to Wood-Gush & Horne (1970), semi-heavy layers during ovulation and oviposition increase the volume of water intake for the processes of formation of the egg components. Another fact that accounts for this higher consumption of water is the ability of the fiber to sequester water from the intestine (Li et al. 2018), with an increase in the amount of fiber ingested in the diet, there is a greater need for water consumption, aiming at maintenance of the intestinal motility and avoiding a paralysis of the digesta inside the gastrointestinal tract.

There was no significant difference ($p > 0.05$) for egg weight, percentage of egg components (yolk, albumen and shell), yolk index, Haugh unit, and albumin and yolk pH (Table III), as well as for variables of external quality, weight,

Table III. Egg weight (g), yolk index, yolk color, percentage of yolk (% yolk), percentage of albumen (% alb), percentage of shell (% shell), Haugh unit (UH), percentage of lipid in the egg (% Lip), pH of albumen (pH alb) and pH of yolk of Japanese quail eggs fed diets containing different levels of crude fiber.

Levels of Crude Fiber (%)	Weight egg (g)	Index of Yolk	Color Yolk	%Yolk	% Alb	% Shell	UH	% Lip	pH alb	pH Yolk
2.78	11.53	0.45	4.5	30.6	61.2	8.2	94.1	13.7	8.77	5.99
3.08	11.49	0.45	4.6	30.5	61.4	8.0	93.5	12.8	9.30	6.20
3.38	11.56	0.45	4.5	30.3	61.4	8.2	93.7	13.0	8.59	5.96
3.68	11.58	0.45	4.8	31.0	61.1	8.1	93.6	13.2	8.84	5.92
3.98	12.16	0.45	5.0	31.1	61.0	8.0	97.1	13.9	8.78	6.04
Regression	NS	NS	L	NS	NS	NS	NS	Q	NS	NS
CV (%)	1.93	2.02	5.50	1.90	0.90	1.65	1.58	9.20	2.72	1.64

NS = non-significant for analysis of regression ($p>0.05$); L = Linear Regression; Equation: $Y = 4.4907+ 0.1437 X$; $p = 0.02$; Q = Quadratic Regression; Equation: $Y = 13.5845 - 1.5757 X + 0.8862 X^2$; $p = 0.0002$; CV = coefficient of variation.

thickness and resistance to shell breakage (Table IV). Güçlü et al. (2004), including alfalfa into laying quail diets (raising the crude fiber concentration from 2.7% to 5.2%), found diets significant improvements in shell thickness, albumen index and Haugh unit. Corroborating with the present study, Duarte et al. (2013) also did not find any differences in the internal and eggshell using different levels of fiber in the quail feeds. Alterations in the external quality of the eggs are expected with fiber rich diets, since these interfere in the absorption and availability of calcium (Duarte et al. 2013), nevertheless, Works on chickens (Van Der Aar et al. 1983) and laying quails (Güçlü et al. 2004) stood out that the feeding of fiber-rich diets did not affect the absorption and content of calcium in the bones and blood of those birds

Yolk color had linear effect, where increased pigmentation of this structure with higher levels of fiber inclusion was found. The influence of fiber content on pigmentation of egg yolks depends on the profile of the fibrous material used and its concentration of carotenoids. Varastegani & Dahlan (2014) reported that leucine leaf meal increased the carcass pigmentation of broiler chickens because of their high pigment concentration. The concentration of such components in the tested material is not known (Opticell).

Table IV. Shell weight (g), shell thickness (mm) and breaking resistance in Kgf (RQ) of eggshell of Japanese quails fed diets containing different levels of crude fiber.

Levels of Crude Fiber (%)	Shell Weight (g)	Shell Thickness (mm)	RQ (Kgf)
2.78	0.94	0.21	1.596
3.08	0.92	0.21	1.420
3.38	0.95	0.21	1.581
3.68	0.94	0.21	1.476
3.98	0.96	0.21	1.495
REGRESSION	NS	NS	NS
CV (%)	1.96	3.27	18.93

NS = non-significant for regression analysis (p>0.05); L* = Linear Regression; Equation: Y = 4.4907+ 0.1437 X; p = 0.02; CV = coefficient of variation.

The lipid concentration in the yolks was influenced in a quadratic manner, so that the inclusion level of 3.08% fiber provided lower lipid concentrations ($p < 0.05$). Güçlü et al. (2004) including alfalfa as a source of fiber for Japanese quails, found a linear reduction in serum levels of triglycerides and cholesterol, and consequently, in the contents of cholesterol in the egg. The fiber has the property of carrying away part of the lipids present in the intestinal lumen, since the cellulose can complex with the lipids forming insoluble complexes, eliminating them together with the excreta (Güçlü et al. 2004).

There were no significant differences ($p > 0.05$) for live weight, relative and absolute weight of gizzard, small intestine and cecum of the quails fed different fiber levels in the diets (Table V). Higher levels of fiber could influence the size of the organs of the GIT of birds, causing an increase in size, since these organs respond rapidly to changes in crude fiber concentration in the diet, modifying intestinal length and organ weight, as well as the rate of passage through the different segments of the gastrointestinal tract (Mateos et al. 2012), a fact not observed in the present experiment. Savory & Gentle (1976) working with Japanese quails fed a conventional diet (low-fiber) and one with high fiber content, and observed that with the increase of fiber, quails improved food intake and presented greater development of the small and large intestine. Braz et al. (2011) used increasing levels of fiber in hen-feeding and found an increase in the relative size of the gut and gizzard of the birds. However, Duarte et al. (2013), as well as in the present study, did not find significant

Table V. Live weight (g), absolute weight of the gizzard(g), relative weight of the gizzard(%), absolute weight of the small intestine (g), relative weight of the small intestine (% small intestine), absolute weight of the cecum (g), relative weight of cecum gizzard (% cecum) of Japanese quails fed diets containing different levels of crude fiber.

Levels of Crude Fiber (%)	Live Weight (g)	Weight Gizzard (g)	% gizzard	Weight small intestine (g)	% small intestine	Weight of the cecum (g)	% cecum
2.78	172.48	3.42	1.99	4.46	2.59	1.20	0.69
3.08	170.72	3.33	1.95	4.46	2.62	0.97	0.57
3.38	174.95	3.37	1.93	4.55	2.60	1.10	0.63
3.68	179.17	3.38	1.89	4.70	2.62	1.23	0.69
3.98	166.89	3.39	2.04	4.27	2.55	1.08	0.65
Regression	NS	NS	NS	NS	NS	NS	NS
CV (%)	6.75	11.86	12.11	12.70	10.53	23.02	21.59

NS = non-significant for analysis of regression (p>0.05); CV = coefficient of variation.

differences for small intestine size and gizzard of Japanese quails fed different levels of fiber.

The inclusion of fiber in the quail diet influenced ($p < 0.05$) the intestinal morphometric characteristics, with a linear effect for the height of the villus in the cecum, so that the highest villus height was found in the cecum of the quails that ingested higher levels of fiber. There was a quadratic effect for the crypt depth and for the villus/crypt ratio of the duodenum, occurring improvements for these variables with the highest inclusion of fiber and reduction the same with the highest level of inclusion, a cubic effect was checked in the regression for height of the villus in the duodenum. There was no significant effect ($p > 0.05$) for the depth of the duodenum crypt and the villus/crypt ratio of the cecum (Table VI). Fiber inclusion increases the population of the beneficial microbiota in both the small intestine and the cecum, reducing the pathogenic one, due to the higher production volatile fatty acids, which are bacteriostatic. These fatty acids are also absorbed by the mucosa of the intestine stimulating the proliferation of intestinal crypt cells, and increasing the renewal of the mucosal wall. On the other hand, the very physical presence of fiber in the small intestine serve to carry the bacteria through the mechanical drag, promoting friction with the wall of the mucosa and thus, eliminating the microorganisms together with the feces (Mateos et al. 2012, Abazari et al. 2016). Wils-Plotz & Dilger (2013) found increased duodenal crypt depth in broilers fed diets containing cellulose. Sabour et al. (2018), including a source of insoluble fiber, and providing a total of crude fiber in the starter, growing and finishing diets for broilers, respectively, of 4.7%, 4.6% and 3.9%, found no significant differences for performance parameters and carcass yield. However, they observed a larger villus size in the duodenum and smaller crypt in the ileum, as well as a better response in the immunological system of the birds and a higher population of beneficial bacteria in the ileum and a smaller one of pathogenic bacteria. Melnik et al. (2014), providing the same source of insoluble fiber used in the present experiment (Opticell®) for broilers challenged with *Escherichia coli* and *Salmonella enteritidis*, found that the birds that received the product obtained greater weight gain even when in contact with the infectious agents and a reduction in the amount of *E. coli* in the intestine was also found.

Table VI. Villus height (mm), crypt depth (mm) and villus/crypt ratio of the duodenum, villus height (mm), crypt depth (mm) and villus/crypt ratio of the cecum of Japanese quails fed diets containing different levels of crude protein.

Levels of Crude fiber (%)	Villus height	Crypt depth	Villus/ Crypt
Duodenum			
2.78	1.02	0.12	8.88
3.08	0.92	0.12	9.39
3.38	0.97	0.12	10.08
3.68	0.90	0.09	10.42
3.98	0.82	0.12	7.34
REGRESSION	C	NS	Q*
CV (%)	20.80	65.99	37.35
Cecum			
2.78	0.51	0.10	5.38
3.08	0.47	0.08	6.04
3.38	0.43	0.07	6.15
3.68	0.49	0.09	5.91
3.98	0.43	0.08	5.84
REGRESSION	L	Q**	NS
CV (%)	23.82	28.69	31.47

C = Cubic regression; Equation: Y = 1.0093 - 0.2630X + 0.3017 X2 - 0.1080 X3; p < 0.0001; Q* = Quadratic regression; Equation: Y = 8.5471+ 3.6531 X - 1.9910 X2; Q = Quadratic regression; Equation: Y = 0.0984 - 0.0322 X + 0.0117 X2; L = Linear regression; Equation: Y = 0.4947 - 0.0322 X; NS = non-significant for regression analysis (p>0.05); CV = coefficient of variation.**

There was no significant difference ($p < 0.05$) for the inclusion of different dietary fiber levels in the moisture rate in the bed of the quails (Table VII). Roque et al. (2006) report that fiber helps gastrointestinal motility, stool consistency, and diarrhea reduction by the increase of water absorption and decrease of the pH of the intestinal environment. Kheravii et al. (2017) using opticell, including from 0 to 2% in broiler diets, observed a reduction in bed moisture with the highest level of fiber inclusion, a fact not observed in the present study. The soluble fiber allows a longer retention time of digesta and a better water-holding capacity of in the intestine, making it possible the reutilization of water in the cecum, reducing the consumption and excretion of water by the bird. In the present study, the increase in water consumption by quails that were given greater inclusion of fiber in the diet could have caused worsening of excreta moisture, due to the greater availability of this element in the intestine, however, the ability of fiber to sequester fluids, as previously discussed, may have prevented increased excreta moisture, making it more difficult to excrete water, maintaining moisture indices and consequently worsening bed quality (Kheravii et al. 2017).

Table VII. Moisture of excreta of Japanese quails fed diets containing different levels of crude fiber.

Levels of Crude Fiber (%)	Moisture (%)
2.78	80.16
3.08	80.52
3.38	81.09
3.68	80.30
3.98	81.32
REGRESSION	NS
CV (%)	2.23

NS = non-significant for regression analysis (p>0.05); CV = coefficient of variation.

Several other studies have also shown that only the variations in dietary fiber content are not sufficient to explain the differences (or similarities) obtained in many of the measures of biological responses evaluated, suggesting that the physicochemical properties of dietary fiber can be altered according to the interactions between their respective insoluble and soluble fractions, as well as with the interaction between the fibers from different origins, which would cause different effects on the digestive and metabolic processes of animals (Monro 2000, 2002).

CONCLUSIONS

The inclusion of the crude fiber levels tested in the laying quail diets influences water consumption, feed conversion, pigmentation and concentration of yolk lipids and morphometry of the duodenum and cecum mucosa. There being no interference in the other performance parameters, egg quality, gizzard weight, small intestine and cecum and excreta moisture.

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