FIBER LEVEL FOR LAYING HENS DURING THE GROWING PHASE

Nível de fibra na fase de crescimento para poedeiras comerciais

Ednardo Rodrigues Freitas[1], Nádia de Melo Braz[2], Pedro Henrique Watanabe[2], Carlos Eduardo Braga Cruz[2], Germano Augusto Jerônimo do Nascimento[2], Roseane Madeira Bezerra[2]

ABSTRACT

Feeding management of laying hens has been focused on the direct influence of nutrient intake on weight gain, especially at growing phase. This study evaluates nutrient digestibility, performance, development of the digestive tract, body composition, and bone quality of two strains of laying hens fed with different levels of neutral detergent fiber (NDF) during the growing phase from the 7th to the 12th week of age. A total of 1,296 birds were distributed in a completely randomized design in a 2 x 3 factorial arrangement (two strains x three levels of NDF) with four replicates of 54 birds per treatment. Semi-heavy (Hy Line Brown) and light-strain (Lohman LSL) pullets were allotted to dietary treatments consisting of 14.50, 16.50, and 18.50% NDF. An interaction between strains and NDF levels was observed only for feed/gain ratio and light-strain pullets had lower performance with 18.50% NDF. The increasing levels of NDF in the diet reduced the coefficients of digestibility of dry matter, nitrogen and gross energy, and the values of metabolizable energy. Higher levels of NDF in the diet increased the relative weight of liver and intestines and reduced gizzard weight. It was also observed differences between bone quality and composition of the femur and tibia of light and semi-heavy hens. The increase in NDF level in ration for growing phase laying hens above 14.50% decreases the nutrient digestibility and the metabolizable energy of the diet; however, it does not affect the carcass composition, bone quality, feed intake, and weight gain, although it may impair feed conversion of light-strain pullets.

Index terms: Growth, insoluble fiber, neutral detergent fiber, strain.

RESUMO

O manejo alimentar de poedeiras tem sido avaliado quanto à influência direta da ingestão de nutrientes no ganho de peso, principalmente na fase de crescimento. No estudo, objetivou-se avaliar os efeitos dos níveis de fibra em detergente neutro (FDN) das rações de recria (7ª e 12ª semanas de idade) sobre a digestibilidade dos nutrientes da ração, desempenho, desenvolvimento do trato digestório, composição corporal e qualidade óssea das aves de duas linhagens de poedeiras comerciais. Foram utilizadas 1.296 aves distribuídas em um delineamento experimental inteiramente casualizado em esquema fatorial dois x três (duas linhagens x três níveis de FDN) com quatro repetições de 54 aves por tratamento. Foram avaliadas aves de uma linhagem de poedeira semipesada (Hy Line Brown) e leve (Lohman LSL) e testados os níveis de 14,50; 16,50 e 18,50% de FDN. Houve interação significativa entre linhagem e nível de FDN sobre a conversão alimentar, com pior desempenho para essa característica em aves de linhagem leve ao nível de 18,50%. O aumento da FDN na ração reduziu os coeficientes de digestibilidade da matéria seca, nitrogênio e energia bruta e os valores de energia metabolizável. Observou-se que o acréscimo de FDN na ração aumentou o peso relativo do fígado e intestinos e reduziu o da moela. Foram observadas diferenças na composição e qualidade óssea do fêmur e tíbia entre as aves de linhagem leve e semipesada. O aumento do nível de FDN na ração de poedeiras na fase de crescimento acima de 14,50% diminui a digestibilidade dos nutrientes e a energia metabolizável da ração, contudo, não afeta a composição da carcaça, a qualidade óssea, o consumo de ração e o ganho de peso, embora, possa prejudicar a conversão alimentar das aves de linhagem leve.

Termos para indexação: Crescimento, fibra insolúvel, fibra em detergente neutro, linhagem.

INTRODUCTION

Although there are different genetic strains for commercial production of eggs, it is agreed that the quality of pullets at the end of the growing phase is critical for the performance of laying hens. Thus, the growing period should have nutritional objectives aimed at producing healthy birds with an ideal body weight, ready to produce at the expected age for a specific commercial strain. Commonly, a variable number of diets are used in feeding programs for growing laying hens, differing in the reduction of nutrient levels as the bird grows. Thus, it is possible to add fibrous feeds, such as wheat bran, to diets offered to hens in order to maintain the low energy density of the diet, thereby avoiding excessive weight gain.

With regard to the fiber content in poultry diets, it has been traditionally recommended to provide the young birds with low fiber diets, since at high amounts there is

[1]Universidade Federal do Ceará – Departamento de Zootecnia – Avenida Mister Hull – 2977 – Campus do Pici – Bloco 807 – Fortaleza – CE – Brasil – ednardo@ufc.br
[2]Universidade Federal do Ceará – Departamento de Zootecnia – Fortaleza – CE – Brasil
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a decrease in energy ingestion, an increase in the transit speed of digesta, and a reduction in nutrient digestibility (Mateos et al., 2012), impairing the performance of the birds. Furthermore, Rath et al. (2000) reported that higher levels of fiber in poultry diets can reduce absorption of calcium in the intestine, resulting in blood hypocalcemia, which may contribute to a reduction of bone development and bone strength. However, some studies have suggested that moderate inclusion of fiber in diet may have benefits in the development of the digestive tract and feed efficiency during the growing phase of birds (Mateos et al., 2012).

Several methods have been used to quantify the fiber fraction of feedstuffs, such as the raw fiber by Weende method, neutral detergent fiber (NDF), and acid detergent fiber (ADF). However, Jeraci and Van Soest (1990) considered that the NDF can be an important measure for the characterization of fiber in poultry feed compared to the other two. Historically, the establishment of a proper definition for dietary fiber present in poultry feed has been based on finding a balance between the nutritional importance and availability of suitable analytical methods with a clear trend to adapt the definition to the existing analysis procedures and not the effects of the fiber fractions on the physiology and health of the gastrointestinal tract (Mateos et al., 2012).

By assessing the literature, it was noted that little attention has been given to the effects of the amount of fiber in diets of growing laying hens. Therefore, the objective of this study was to evaluate the effects of increasing levels of neutral detergent fiber (NDF) in laying hen diets of two strains during the growing phase on the dietary nutrient digestibility, performance, development of the digestive tract, body composition, and bone quality.

MATERIAL AND METHODS

A total of 1600 one-day-old chicks from two strains were raised to conduct the experiment, divided into semi-heavy (Hy Line Brown) and light (Lohman LSL) strains. In the initial phase (up to 6 weeks of age), the birds were kept on a deep-litter floor and managed according to the phase recommendations of each strain. In addition, chicks were vaccinated according to the regional vaccination program routine. After the 6th week, the birds were weighed and selected to obtain experimental plots with average weight within each strain. After selection, 1296 birds aged from 7 to 12 weeks of age were distributed into a completely randomized design in a 2 x 3 factorial arrangement (two strains x three levels of NDF), amounting 6 treatments and four replicates with 54 birds each. Dietary treatments consisted of 14.50, 16.50 and 18.50% of NDF levels. The birds were housed in wire-mesh rearing cages (50 cm x 50 cm x 45 cm), with a gutter-type feeder and nipple drinker. The total of 54 birds of each replicate was divided according to the capacity of the cage (nine birds/cage), totaling six cages per replicate. The experimental diets (Table 1) were formulated to be isonutrient, except for the level of NDF, according to the commercial management guide. On the basis of the similarity of the nutritional requirements for the strains used, the same diet was used for both.

During the experimental period, birds were fed *ad libitum*. To evaluate the performance, birds, diets and leftovers were weighed to determine the final weight of birds, weight gain, accumulated intake and feed conversion.

Nutrient digestibility of diets was determined in a metabolism trial, using the method of total excreta collection. The assay was conducted during the performance assay, between the 11th and 12th week of age and lasted four days. The collections of excreta per cage were done twice daily (8:00am and 4:00pm) and stored in an identified container. At the end of the experimental period, a composite sample of excreta per cage was obtained. Feed intake and total excreta production per cage were determined to determine the nutrient digestibility and energy metabolizability of diets. Samples of diets and excreta were analyzed for dry matter (DM), nitrogen (N), and ether extract (EE), according to AOAC (2005). The gross energy was determined in an adiabatic calorimeter bomb (Model 1242, Parr Instruments Co. EUA.). Based on analysis, coefficients of digestibility of dry matter (DMDC), ether extract (EEDC), crude protein (CPDC), and gross energy (GEDC) were calculated. The values of apparent metabolizable energy (AME) and apparent metabolizable energy of diets corrected for nitrogen balance (AMEn) were calculated based on Matterson, Potter and Stutz (1965).

At 12 weeks of age, four birds per cage with similar average weight of the plot were selected and submitted to 24 hours of fasting and slaughtered. Plucked carcasses were weighed, packed in plastic sheets and frozen in a freezer (-10º C) until processing for analysis. Subsequently, the frozen carcasses were sawn and milled. Samples of carcasses were weighed and placed in a forced air ventilation stove at 55° C for 72 hours for pre-drying and subsequently milled in a ball mill and sent to the laboratory for determination of dry matter (DM), ether extract (EE), crude protein (CP), and mineral matter (MM) according AOAC (2005). Based on the results, carcass composition of two birds per cage was calculated.

Table 1 – Calculated and nutritional composition of experimental diets used for commercial laying hens in the laying and growing phases.

Ingredient	1st to 6th week	NDF level (g/kg)		
		7th to the 12th week		
		145	165	185
Corn	640.0	605.7	573.6	485.9
Soybean meal	320.0	231.3	215.1	247.9
Wheat meal	0.0	106.3	170.4	205.0
Soybean oil	0.0	0.0	3.4	23.9
Inert material (washed sand)	0.0	18.8	0.0	0.0
Monobicalcium phosphate	18.4	15.8	15.1	14.4
Limestone	13.4	15.1	15.4	15.6
Salt	3.5	3.6	3.6	3.6
DL-methionine	0.7	1.4	1.4	1.4
Vitamin and mineral premix[1]	4.0	0.0	0.0	0.0
Vitamin supplement[2]	0.0	1.0	1.0	1.0
Mineral suplement[3]	0.0	0.5	0.5	0.5
L-lysine HCl	0.0	0.5	0.7	0.7
Total	100	100	100	100
Calculated nutritional composition				
Metabolizable energy (kcal/kg)	2,920	2,800	2,800	2,800
Crude protein (g/kg)	201.0	175.0	175.0	175.0
Crude fiber (g/kg)	31.4	35.0	39.2	43.8
NDF (g/kg)	118.4	145.0	165.0	185.0
ADF (g/kg)	46.8	50.7	55.6	60.5
Calcium (g/kg)	10.0	10.0	10.0	10.0
Available phosphorus (g/kg)	4.7	4.3	4.3	4.3
Total lysine (g/kg)	10.5	9.0	9.0	9.0
Total methionine + cysteine (g/kg)	8.1	7.1	7.1	7.1

[1]Mineral vitamin supplement (composition per kg of the product): vit. A – 1,775,000 IU; vitamin B12 – 2,280 mcg; vitamin D3 – 450,000 IU; vitamin E – 2,275 mg; vitamin K – 325 mg; folic acid – 113 mg; niacin – 5,750 mg; pyridoxine – 450 mg; colitis – 1,750 mg; riboflavin – 1,125 mg; thiamine – 450 mg; calcium pantothenate – 2,275 mg; choline – 66,000; biotin – 11.30 mg; antioxidant – 500mg; Silicate – 10,000 mg; Co – 25.00 mg; Cu – 2,500 mg; Fe – 6,250 mg; I – 260mg; Mn – 13,000 mg; methionine – 225g; Se – 45,00 mg; Zn – 11,100 mg.
[2]Vitamin supplement (composition per kg of the product): vit. A – 6,000,000 IU; vit. D3 – 2,000,000 IU; vit. E – 12,000 mg; vit. K3 – 2,000 mg; vit. B1 – 2,200 UI; vit. B2 – 5,000; vit B6 – 2,300 mg; vit. B12 – 12,000 mcg; niacin – 28,000 mg; folic acid – 600 mg; pantothenic acid – 11,000 mg; antioxidant – 15 mg; biotin – 20 mg; selenium – 200 mg.
[3]Mineral supplement (composition per kg of the product): Mn –130,000 mg; Zn – 100,000 mg; Fe – 80,000 mg; Cu – 24,000 mg; I – 2,000 g; q.s.p. vehicle.

Two other birds per cage were slaughtered without fasting for the removal of digestive tract organs (gizzard, liver, and intestines), thighs, and drumsticks. Liver, gizzard, intestine and contents were weighed. After weighing, the pH of gizzard and intestine contents was measured with a pH meter. The weight of digestive tract organs were expressed as a percentage of body weight. To assess bone quality, thighs and drumsticks were identified and frozen in a freezer (-10º C) until processing for analysis. The tibia and femur from the legs were collected, cleaned of soft tissues, and measuring the weight and length. The bone density (mg/mm) was performed using the Seedor index (Seedor, 1991) and strength parameters of resistance and deformity was determined using a mechanical press according to Cruz et al. (2012). The bones from the right leg were weighed and placed in a forced ventilation oven at 55° C for 72 h, grounded in a ball mill and analyzed for DM, CP, and MM content (AOAC, 2005).

Data were analyzed using the ANOVA procedure of SAS program (STATISTICAL ANALYSIS SYSTEM, version of 9.2) for a factorial arrangement and means were compared by SNK test at 5% probability.

RESULTS AND DISCUSSION

There was no significant interaction between the factors level of NDF and strain on the determined coefficients of digestibility and metabolizable energy (Table 2). Regarding the effect of the fiber, it was found that the coefficients of digestibility of dry matter, nitrogen and gross energy, and the values of AME and AMEn decreased as levels of NDF were increased. There was no significant difference between the coefficients of digestibility determined with both strains; however, higher values of AME and AMEn of the diets for semi-heavy birds were found.

The reduction in nutrient digestibility with the addition above 14.50% of NDF in the diet can be associated with adverse effects of an increase in the dietary fiber fraction and the characteristics of the fiber fraction of wheat bran, which was used to achieve the NDF levels. It has been reported in literature that the increase in fiber content in poultry diets may impair nutrient utilization (Bedford; Partridge 2001). Regarding the use of wheat bran in diets for broilers, Annison and Choct (1991) affirmed this feedstuff increases intestinal viscosity because its fiber fraction is rich in soluble non-starch polysaccharides (NSPs) such as arabinoxylans, which cause a general inhibition of feed digestion affecting digestibility of carbohydrates, fats, and proteins, and these effects are more pronounced in younger birds.

Table 2 – Effect of the levels of NDF on the coefficient of digestibility of nutrients and values of apparent metabolizable energy and apparent metabolizable energy corrected for diets of pullets on the growing phase (7 to 12 weeks of age).

Item	Variable					
	DMCD (%)	NCD (%)	GECD (%)	EECD (%)	AME (kcal/g DM)	AMEn (kcal/g DM)
NDF level (%)						
14.5	74.98a	54.88a	80.62a	84.61	3,353a	3,177a
16.5	74.59a	48.86b	77.32b	84.65	3,247b	3,130b
18.5	71.67b	48.06b	74.66c	84.26	3,207b	3,079c
Strain						
Light	73.18	49.87	77.13	84.11	3,234b	3,101b
Semi-heavy	73.97	51.33	77.93	84.90	3,303a	3,155a
Effects - ANOVA[1]	*p*-value					
Level	0.001	0.001	0.001	0.001	0.001	0.001
Strain	0.085	0.076	0.132	0.589	0.002	0.015
Level x Strain	0.240	0.323	0.590	0.365	0.632	0.660
CV (%)	1.71	5.44	1.34	1.73	1.10	1.11

Means followed by different letters in the column differ from each other by the SNK test (5%); [1] – Analysis of variance; [Ns] Non-significant; * Significant effect at 5% of probability ($P<0.05$).
DMCD – dry matter coefficient of digestibility; NCD – nitrogen coefficient of digestibility; GECD – Gross energy coefficient of digestibility; EEDC – ether extract coefficient of digestibility; AME – apparent metabolizable energy; AMEn – apparent metabolizable energy correct for nitrogen.

Although no difference between the coefficients of digestibility of diets for semi-heavy and light strains was found, the highest values determined with semi-heavy pullets indicate a higher metabolization of dietary energy, possibly due to the morphophysiological characteristics of the digestive tract of this strain. Uni, Noy and Sklan (1995) observed a greater villus volume, enterocyte density, and enzyme secretion into the duodenum in heavy-strain chicks compared to light-strain chicks. Regarding the performance of pullets, there was a significant interaction among strain and NDF levels only for feed conversion (Table 3). It was also found that the final average weight, total weight gain, and accumulated feed intake did not vary significantly between assessed levels of NDF, but they significantly differed between strains.

Semi-heavy birds had higher initial and final weights, and weight gain, and had better feed conversion, compared to light-strain pullets. These differences in performance among strains are consistent with the literature, and according to Neme et al. (2006), due to the growth characteristics imposed by breeding programs used in each strain, since the light-strain laying hens are selected for lower body weight at maturity and that makes these birds have less weight gain than the semi-heavy pullets during the growing phase. In turn, the best feed conversion of semi-heavy birds is due to the increased rate of weight gain of these birds during this stage of the growing period. It was found that the light-strain birds fed a diet containing 18.50% NDF presented a worse feed conversion compared to birds fed 14.50% NDF (Table 4). Decreasing the metabolizable energy of diets according to dietary levels of NDF and the reduction in nutrient digestibility resulted in reduced feed conversion.

No interaction between the studied factors on the digestive tract variables. (Table 5). However, it was found that the size of the liver, gizzard, and intestinal contents varied significantly among the strains and that there were significant differences among the levels of dietary NDF. The NDF level of the diet did not significantly influence the pH of the gizzard content. The higher retention time of the fiber fraction in the gizzard can reduce the pH of the bolus (Hetland et al., 2005); although, according to the results, the changes in the level of dietary NDF were insufficient to promote changes in the pH of gizzard content in the present study. The higher liver and intestine weights observed with 18.5% of NDF in the diet can be associated to negative effects of fiber on digestion and absorption of nutrients, and to the fibrous fraction of wheat bran, which may increase intestinal viscosity and change enteric morphology and physiology, thus modifying the passage rate and deregulating hormone function, inducing greater activity of these organs and increasing the relative weight

Table 3 – Effect of the different levels of neutral detergent fiber (NDF) on performance of light and semi-heavy birds during the growing phase.

Item	Variable				
	Initial weight (g)	Final weight (g)	Weight gain (g/bird)	Accumulated intake (g/bird)	Feed conversion
NDF level (%)					
14.5	526.11	1016.45	490.34	1921.39	3.93
16.5	526.95	1016.12	489.17	1925.17	3.95
18.5	525.85	1010.86	485.01	1940.81	4.03
Strain					
Light	520.27b	977.85b	457.58b	1916.71	4.19
Semi-heavy	532.34a	1051.09a	518.76a	1941.54	3.74
Effects - ANOVA[1]			*p*-value		
Level	0.729	0.723	0.775	0.729	0.044
Strain	0.001	0.001	0.001	0.252	0.001
Level x strain	0.858	0.235	0.214	0.847	0.038
CV (%)	0.55	1.52	3.20	2.67	1.97

Means followed by different letters in the column differ from each other by the SNK test (5%); ^{Ns} Non-significant; * Significant effects at 5% of probability (P<0.05).

of them. According to Marcato et al. (2010), the liver is the main metabolic organ of body, thus nutritional factors might interfere its function and the change in size of this organ may be caused by modulation of metabolic activity. Thereby, due to the NSP adsorption capacity by biliar salts, the higher relative liver weight of pullets fed with increasing levels of NDF may occur according to higher activity of this organ.

Table 4 – Effect of the different levels of neutral detergent fiber (NDF) on feed conversion of light and semi-heavy laying hens during the growing stage.

Strain	NDF level (%)			Mean
	14.5	16.5	18.5	
Light	4.10Ab	4.17Aab	4.31Aa	4.19
Semi-heavy	3.75Ba	3.73Ba	3.75Ba	3.74
Mean	3.93	3.95	4.03	

Means followed by lower case letters (row) and upper case letters (column) do not differ among each other by the SNK test (5%).

Table 5 – Effect of the different levels of neutral detergent fiber (NDF) on the relative weight of organs of light and semi-heavy strains during the growing phase (7th to 12th week).

Item	Variable				
	Liver (%)	Gizzard (%)	Gizzard content pH	Intestine (%)	Intestine content (g)
NDF level (%)					
14.5	1.88b	2.95a	3.22	3.04b	22.62b
16.5	1.99a	2.76ab	3.25	3.21ab	21.84b
18.5	1.96a	2.65b	3.31	3.39a	27.65a
Strain					
Light	1.98a	2.52b	3.17	3.17	18.82b
Semi-heavy	1.90b	3.06a	3.34	3.25	29.26a
Effects – ANOVA[1]	*p*-value				
Level	0.011	0.033	0.896	0.005	0.007
Strain	0.006	0.001	0.294	0.333	0.001
Level x strain	0.479	0.295	0.572	0.137	0.462
CV (%)	3.4	7.4	12.06	5.76	14.36

Means followed by different letters in the column differ from each other by the SNK test (5%); [1] – Analysis of variance; [Ns] Non-significant.

Although the increased level of NDF in the diet could promote reduction in performance, this practice can bring beneficial effects on the development of digestive tract organs because insoluble fiber plays an important physiological role in the digestive process, interacting with the functions of the intestine (Hetland; Svihus; Choct, 2005), supporting the hypothesis that the birds might have a requirement for fiber to promote stimulation of the digestive tract.

The light-strain birds showed higher relative liver weight, lower relative weights of gizzard, and less content in the intestine compared to the semi-heavy hens due to changes in the physiological aspects of the birds from breeding programs used in the preparation of each strain. The weight of the liver of laying hens increases in the periods prior to laying (Hazelwood et al., 1986) thus the higher relative liver weight may be associated with the precocity of light laying hens, since the onset of reproductive activity of the females implies an increase in the activity of this organ, due to the reason for effective synthesis of available energy to lipid for yolk formation (Tesfaye et al., 2009). The results obtained in this study agree with those obtained by Figueiredo et al. (2002) e Marcato et al. (2010), who found that commercial strains of broilers with higher metabolic activity showed greater relative liver weight.

For the carcass composition of birds at 12 weeks of age (Table 6), it was observed that there was no significant interaction between the strain and NDF level on the evaluated parameters. The NDF level in diet did not influence the proportion of dry matter, crude protein, ether extract, or ash in the carcass. However, dry matter, crude protein, and ether extract content varied significantly between strains.

The changes in the body composition of hens, particularly with regard to the relationship between crude protein and fat, occur as they grow older and, therefore, an appropriate body composition has been related to the first physiological signals of the development of the reproductive system (Neme et al., 2006). Corroborating the results found in the present work, Almasi et al. (2012) also observed that old sire strain of cocks presented low development of muscle tissue compared to the new sire strain, and considering the metabolism activity of both, the elderly strain have continued to develop muscle tissue for a longer period. Similarly, in accordance with the same authors, cocks of recent strains with faster growing deposited more fat compared to elderly strains during the growing phase. Considering that fat deposition is directly proportional to the amount of available energy for synthesis; to maximize the daily deposition of protein and minimize fat deposition is necessary to avoid excessive energy intake. Thus, it has been reported that increasing dietary fiber fraction may decrease the utilization of nutrients and therefore, reduce the metabolizable energy of feed and decrease growth rate of birds (Bedford, 1995). Thus, because in the present study the diets were formulated to be isonutrient except for NDF and there were no significant differences in feed intake and weight gain by increasing the level of NDF in the diet, it can be stated that the intake and utilization of nutrients are sufficient to ensure deposition of the constituents similar to the constituents of the carcass of the birds, even with the addition of fiber into the diet.

The many strains of laying hens may have different deposition rates of chemical components, which will directly influence the body composition of the bird (Gous et al., 1999). Because the light hens are selected for lower body weight at maturity, these birds reach the mature body weight more quickly than semi-heavy hens since they reach the highest rates of physical development in less time. At sexual maturity, in addition to the proper body weight, birds need an ideal carcass composition because both appear to have an effect on egg weight (Neme et al., 2006). According to Marcato et al. (2009), the potential for growth and tissue deposition are influenced by strain, sex, and growth stages, and as the birds grow older, there is naturally more body fat deposition, which is related to the relative maturity while the deposition of lean meat or protein is controlled by genetics.

Evaluating bone quality, no interaction between strain and NDF level was noted (Table 7). It was observed that the level of NDF in the diet did not significantly influence the growth, quality, or composition of the femur and tibia of pullets at 12 weeks of age. Between the strains, there were significant differences for length, weight, Seedor index, strength, and femur and tibia composition. However, the dry matter and deformity of the bones did not vary significantly. The semi-heavy hens presented larger and heavier femurs, with lower mineral content and reduced bone strength compared to light hens, with no significant difference in dry matter and bone deformity between strains. For the tibia, it was found that the semi-heavy birds displayed significantly heavier and longer bones, with higher Seedor index and bone strength, and lower mineral content than the light birds, with no significant difference in dry matter and bone deformity between strains.

According to Whitehead (2004), the genetic divergence is well demonstrated in the development and bone quality between strains of hens, and this must be considered in breeding programs today. According to this author, some strains present greater ability to deposit bone mass structure and also larger reticulate in cartilage matrix of bone, leading to an increased breakage of bones resistance.

Table 6 – Body composition of light and semi-heavy birds at 12 weeks of age fed different levels of neutral detergent fiber during the growing stage (7 to 12 week of age).

Item	Variable			
	Dry matter (%)	Crude protein (%DM)	Ether extract (%DM)	Ash (%DM)
NDF level (%)				
14.5	31.21	20.41	11.47	3.46
16.5	30.57	21.17	10.64	3.46
18.5	30.39	21.75	10.48	3.12
Strain				
Light	32.01a	21.64a	11.49a	3.30
Semi-heavy	29.44b	20.58b	10.24b	3.39
Effects – ANOVA[1]	*p*-value			
Level	0.1303	0.0807	0.3635	0.0670
Strain	0.0001	0.0310	0.0492	0.3443
Level x strain	0.5378	0.3940	0.2929	0.8440
CV (%)	2.64	5.27	13.33	6.53

[1]Means followed by different letters in the column differ from each other by the SNK test (5%).

Table 7 – Effect of the different levels of neutral detergent fiber (NDF) of the growth diet (from the 7th to the 12th week of age) on the bone quality and composition of the femur and tibia of light and semi-heavy hens at 12 weeks of age.

Item	Variable						
	Weight (g)	Length (mm)	Seedor index (mg/mm)	Strength (kgf/cm^2)	Deformity (mm)	Dry matter (%)	Mineral matter (%)[2]
				Femur			
NDF levels (%)							
14.5	4.00	72.15	55.37	8.59	3.11	75.91	37.28
16.5	4.17	73.18	56.94	8.34	3.54	78.62	38.12
18.5	3.92	72.21	54.26	7.08	3.42	75.30	38.59
Strain							
Light	3.73b	71.49b	52.12b	9.27[a]	3.45	75.07	38.48a
Semi-heavy	4.34a	73.53a	58.93[a]	6.73b	3.26	77.88	37.52b
Effects – ANOVA[1]	*p*-values						
Level	0.315	0.295	0.093	0.305	0.483	0.212	0.065
Strain	0.001	0.001	0.001	0.007	0.536	0.106	0.038
Level x strain	0.729	0.801	0.726	0.218	0.719	0.977	0.227
CV (%)	4.35	1.09	4.15	25.48	21.52	5.28	2.76
				Tibia			
NDF levels (%)							
14.5	5.51	104.91	52.43	4.08	3.07	75.76	40.59
16.5	5.38	105.10	51.11	4.08	3.41	78.50	41.07
18.5	5.27	106.03	49.72	4.17	3.32	75.36	41.17
Strain							
Light	4.79b	104.55b	45.80b	3.15b	3.18	76.57	41.85a
Semi-heavy	5.98a	106.15a	56.37a	5.07a	3.35	76.51	40.03b
Effects – ANOVA[1]				*p*-value			
Level	0.346	0.175	0.132	0.964	0.636	0.091	0.625
Strain	0.001	0.005	0.001	0.001	0.569	0.957	0.002
Level x Strain	0.593	0.704	0.195	0.112	0.166	0.875	0.483
CV (%)	5.80	1.16	4.98	19.09	21.95	3.81	3.10

[1]Means followed by different letters in the column differ from each other by the NSK test (5%); [2] values expressed in the dry matter.

According to Rath et al. (2000), data from some studies suggest the genetic potential for birds with higher body weight to have larger and stronger bones. Bishop et al. (2000) found that bone strength has a positive correlation with the weight of the birds, indicating that the heavier birds tend to have stronger bones, although sometimes they are not strong enough to withstand the excess weight. These facts justify the larger size and greater weight of the femur and tibia weight and density measured by the Seedor index of semi-heavy birds.

Regarding differences in bone composition of the strains used in this study, they can be attributed to the growth characteristics of each strain. According to Neme et al. (2006), the white birds are more precocious and therefore reach sexual maturity earlier than the brown ones, since they present higher rates of body growth in less time, as well as deposition of body ash. Extending these events to bone growth, it is possible that the light birds, at a certain time of the growth curve, might show bones with higher levels of these constituents.

CONCLUSIONS

The increase in NDF level in ration for growing phase laying hens above 14.50% decreases the nutrient digestibility and the metabolizable energy of the diet; however, it does not affect the carcass composition, bone quality, feed intake, and weight gain, although it may impair feed conversion of light-strain pullets.

REFERENCES

ALMASI, A. Effect of age, sex and strain on growth, body composition and carcass characteristics of dual purpose type chicken. **World´s Poultry Science Journal**, Supplement 1, p.47-50, 2012.

ANNISON, G., CHOCT, M. Anti-nutritive activities of non-starch polysaccharides in broiler diets and strategies minimizing their effects. **World´s Poultry Science Journal**, 47:232-242, 1991.

AOAC – Association of Official Analytical Chemists - **Official methods of analysis of the Association Analytical Chemists**. 18 ed. Gaithersburg, Maryland, 2005. 1298p.

BEDFORD, M.R. Mechanism of action and potential environmental benefits from the use of feed enzymes. **Animal Feed Science and Technology**, 53:145-155, 1995.

BEDFORD, M.R.; PARTRIDGE, G.G. **Enzymes in Farm Animal Nutrition**. CABI. Publishing. Ed. Finnfeeds International, Marlborough, Wiltshire, UK. 2001. 432p.

BISHOP, S.C. et al. The inheritance of bone characteristics affecting osteoporosis in laying hens. **British Poultry Science**, 41:33-46, 2000.

CRUZ, C.E.B. et al. Bone quality of laying hens fed different levels of fiber in the growth phase (7 to 17 weeks of age). **Revista Brasileira de Zootecnia,** 41:2032-2038, 2012.

FIGUEIREDO, E.A.P. et al. Peso e tamanho de órgãos de diferentes linhagens de frangos de corte. **Revista Brasileira de Ciência Avícola**, Suplemento 4, p.95, 2002.

GOUS, R.M. et al. Evaluation of the parameters needed to describe the overall growth, the chemical growth, and the growth of feathers and breast muscles of broilers. **Poultry Science**, 78:812-821, 1999.

HAZELWOOD, R.L. Carbohydrate metabolism. In: STURKIE, P.D. **Avian physiology**. New York, D.C., 1986. p.303-325.

HETLAND, H., SVIHUS, B., CHOCT, M. Role of insoluble fiber on gizzard activity in layers. **Journal Applied Poultry Research,** 14:38-46, 2005.

JERACI, J.L., VAN SOEST, P.J. Improved methods for analysis and biological characterization of fiber. **Advances in Experimental Medicine and Biology**, 270:245-263, 1990.

MARCATO, S.M. et al. Crescimento e deposição de nutrientes nas penas, músculo, ossos e pele de frangos de corte de duas linhagens comerciais. **Ciência e Agrotecnologia**, 33(4):1159-1168, 2009.

MARCATO, S.M., et al.; Crescimento e deposição de nutrientes nos órgãos de frangos de corte de duas linhagens comerciais. **Revista Brasileira de Zootecnia,** 39:1082-1091, 2010.

MATEOS, G.G. et al. Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. **Journal of Applied Poultry Research,** 21:156-174, 2012.

MATTERSON, L.D., POTTER, L.M., STUTZ, N.W. The metabolizable energy of feed ingredients for chickens. **Research Report**, 7:3-11, 1965.

NEME, R. et al. Curvas de crescimento e de deposição dos componentes corporais em aves de postura de diferentes linhagens. **Revista Brasileira de Zootecnia**, 35:1091-1100, 2006.

RATH, N.C. et al. Factors regulating bone maturity and strength in poultry. **Poultry Science**, 79:1024-1032, 2000.

SEEDOR, J.G. The biophosphanate alendronate (MK-217) inhibit bone loss due to ovariectomy in rats. **Journal of Bone and Mineral Research**, 6:339-346, 1991.

TESFAYE, E. et al. Effects of feed restriction on production and reproductive performance of Rhode Island red pullets. **African Journal of Agricultural Research**, 47:642-648, 2009.

UNI, Z., NOY, Y., SKLAN, D. Post hatch changes in morphology and function of small intestines in heavy and light strain chicks. **Poultry Science,** 74:622-1629, 1995.

WHITEHEAD, C.C. Overview of bone biology in the egg-laying hen. **Poultry Science**, 83:193-199, 2004.