



## Effect of feed restriction with voluntary hay intake on the performance and quality of laying hen eggs

Rafaele Ferreira Moreira<sup>1\*</sup>, Ednardo Rodrigues Freitas<sup>2</sup>, Francislene Silveira Sucupira<sup>1</sup>, Alisson Lucas Freitas Diógenes<sup>1</sup>, Mário Sérgio Abe<sup>1</sup> and Francisco Wander Soares Araújo<sup>1</sup>

<sup>1</sup>Programa de Pós-graduação em Zootecnia, Universidade Federal do Ceará, Cx. Postal 12167, 60021-970, Fortaleza, Ceará, Brazil. <sup>2</sup>Departamento de Zootecnia, Universidade Federal do Ceará, Fortaleza, Ceará, Brazil. \*Author for correspondence. E-mail: rafaelefm@gmail.com

**ABSTRACT.** The objective was to evaluate the effect of a quantitative feed restriction on the voluntary intake of hay, the performance of laying hens, and on egg quality. A total of 150 Hisex Brown laying hens at 51-weeks old were distributed into five treatments and five replications of six hens each. The treatments consisted of control, with supply of 100 g of feed bird<sup>-1</sup> day<sup>-1</sup> without hay; and the others consisting of a feed restriction of 5, 10, 15 and 20% of the diet offered to the birds in the control treatment, along with an ad libitum supply of cunhã hay (CH), leucaena leaf meal (LLM) and tifton hay (TH). A linear increase was found in the hay intake with increasing level of dietary restriction. However, egg production, egg weight, egg mass and feed conversion decreased linearly. Yolk color was affected by the treatments. Birds with 20% feed restriction presented the greatest yolk pigmentation. In conclusion, laying hens can be subjected to a 5% feed restriction with supply of hay ad libitum.

**Keywords:** dietary restriction, hay intake, commercial laying hens, fodder.

### Efeito da restrição alimentar com oferta de feno sobre o desempenho e a qualidade dos ovos de poedeiras

**RESUMO.** O objetivo da pesquisa foi avaliar o efeito da restrição alimentar sobre a ingestão voluntária de feno, o desempenho das aves e a qualidade dos ovos. Foram utilizadas 150 poedeiras da linhagem Hisex Brown com 51 semanas de idade. As aves foram distribuídas em cinco tratamentos com cinco repetições de seis aves cada. O tratamento controle consistiu no fornecimento de 100 g de ração ave<sup>-1</sup> dia<sup>-1</sup> sem oferta de feno e os demais na oferta de 95, 90, 85 e 80 g de ração ave<sup>-1</sup> dia<sup>-1</sup>, que corresponderam, respectivamente, às restrições de 5, 10, 15 e 20% da quantidade de ração, com o fornecimento de feno à vontade. Foram utilizados os fenos de cunhã, das folhas de leucena e de tifton. Com o aumento no nível de restrição, houve aumento no consumo diário de feno, redução na produção, na massa de ovo, no peso médio das aves e piora na conversão alimentar. Em relação às características de qualidade dos ovos, apenas a coloração da gema variou entre os tratamentos, obtendo-se gemas mais pigmentadas com o nível de 20% de restrição. As poedeiras podem ser submetidas a 5% de restrição da ração de postura, com o fornecimento de feno à vontade.

**Palavras-chave:** restrição de ração, ingestão de feno, poedeiras comerciais, forrageiras.

### Introduction

The great demand from consumers for products with different attributes has influencing changes in the systems used for poultry production (BUCHANAN et al., 2007). In this way the poultry production under the free-range system for the production of meat and eggs is a segment of the alternative aviculture, which has been promising, particularly among small and medium rural producers that offer to the consumer market differentiated product.

The poultry production in the free-range system to be feasible should be directed to the use of alternative feeding and pastures. In the free-range system, the feeding of birds with exclusively commercial diet may

cause losses, even selling the eggs with a price higher than the recommended for eggs produced industrially. According to Souza et al. (2008), the consumption of forage by birds is low, and the balanced, supplementary diet is undoubtedly necessary to maintain a good health and high levels of poultry production. Paterson et al. (2000) reported that the feasibility of forage use in the dietary of laying hens under free-range system is related to the increase in the yolk pigmentation, the reason why there is greater popular preference and justifies the higher price in their commercialization.

According to Souza et al. (2008), make the birds consume forage is necessary the dietary restriction. In this condition, the supply of concentrate can be reduced from 20 to 30% in the feed consumed ad

libitum by the birds, creating conditions for the supply of alternative foods, such as legumes, grasses, and other plant sources. For these authors, the restriction level should be established based on the availability of raw materials for feeding and on the year season, but, the adoption of this practice should be evaluated carefully, due to the lack of precise technical information regarding the effects on the production.

Given the need of studies that may support the nutrition plan of hens for egg production under a semi-confinement system, the present study aimed to evaluate the effect of dietary restriction on the voluntary hay intake, performance, and the egg quality of laying hens.

## Material and methods

A total of 150 Hisex Brown laying hens at 51-weeks old, and  $1,780 \pm 80$  g in average weight were used in this experiment. The hens were distributed into a completely randomized design with five treatments and five replications of six hens each. The animals were housed in galvanized wire cages (25 x 40 x 30 cm; one bird per cage). Each cage had a nipple drinker and individual trough-feeder.

The control treatment consisted of a supply of 100 g bird<sup>-1</sup> day<sup>-1</sup> of the laying diet (Table 1) without supply of hay and the other treatments referring to the supply of 95, 90, 85 and 80 g bird<sup>-1</sup> day<sup>-1</sup>, corresponding respectively to the restrictions of 5, 10, 15 and 20% of the amount of laying diet given to the control group, with ad libitum hay supply.

**Table 1.** Percent composition of the laying diet.

| Ingredients                                   | kg     |
|-----------------------------------------------|--------|
| Corn                                          | 64.65  |
| Soybean meal                                  | 23.82  |
| Limestone                                     | 9.10   |
| Monodicalcium phosphate                       | 1.56   |
| Regular salt                                  | 0.39   |
| Vitamin supplement <sup>1</sup>               | 0.20   |
| Mineral supplement <sup>2</sup>               | 0.10   |
| DL- Methionine                                | 0.16   |
| L- lysine                                     | 0.02   |
| Total                                         | 100.00 |
| Calculated composition                        |        |
| Metabolizable energy (kcal kg <sup>-1</sup> ) | 2,719  |
| Crude protein (%)                             | 16.50  |
| Neutral detergent fiber (%)                   | 10.89  |
| Acid detergent fiber (%)                      | 4.22   |
| Lysine (%)                                    | 0.84   |
| Methionine + cystine (%)                      | 0.70   |
| Methionine (%)                                | 0.42   |
| Threonine (%)                                 | 0.64   |
| Total tryptophan (%)                          | 0.19   |
| Calcium (%)                                   | 3.90   |
| Available phosphorus (%)                      | 0.40   |
| Sodium (%)                                    | 0.19   |

<sup>1</sup>Composition per kg of product: Vit. A - 3,500,000 UI; Vit. B<sub>1</sub> - 1,000 mg; Vit. B<sub>2</sub> - 1,500 mg; Vit. B<sub>12</sub> - 4,000 mg; Vit. D<sub>3</sub> - 750,000 UI; Vit. E - 2,000 mg; Vit. K<sub>3</sub> - 1,000 mg; Choline chloride: 250 mg; Niacin: 7,500 mg; Selenium: 150 mg; Calcium Pantothenate: 2,500 mg; Antioxidant: 25 g; Inert to complete 1,000 g. <sup>2</sup>Composition per kg of product: Mn - 65,000 mg; Zn - 50,000 mg; Fe 50,000 mg; Cu - 12,000 mg; I - 1,000 mg; Inert to complete 1,000 g.

To establish the amount of the laying diet supplied for each treatment, it was performed the control of the average consumption of ration before starting the experiment. We determined the daily consumption of 100 g bird<sup>-1</sup> day<sup>-1</sup>, which was used as a basis to apply the restrictions.

To ensure that birds subjected to dietary restriction were separately fed the ration and the three types of hay, the 25 cm of trough-feeder available for each bird were equally divided into four parts to supply the ration and the three types of hay.

The laying diet (Table 1) was formulated to meet nutritional requirements according to the recommendations proposed by the handbook of the Euribrid Hisex (2001). For the calculation, it was considered the composition values of the ingredients suggested by Rostagno et al. (2005).

The used hays were: cunhã hay (*Clitoria ternatea* L.), leucaena leaf meal (*Leucaena leucocephala*) and tifton hay (*Cynodon niemfluisis* - cv. 85).

The experimental period lasted 63 days, divided into three periods with 21 days each. At the beginning of each period, the hays were weighed in equal amounts for all the birds, and the diets, weekly.

Throughout experimental period, the birds received water ad libitum. The diet designed for each replication was given each morning and the refill of the hays was made whenever necessary.

The hens were subjected to the light for 16h day<sup>-1</sup>, receiving 4h of artificial light besides the natural light.

The temperatures were measured twice a day, using thermometers of maximum and minimum values. The average temperature during the experiments was 27.15°C and  $29.45 \pm 0.78$ °C the average of the maximum values, and  $24.85 \pm 0.49$ °C, of the minimum ones. The average of relative humidity was 68%.

The performance variables evaluated were: diet intake (g bird<sup>-1</sup> day<sup>-1</sup>), hay intake (g bird<sup>-1</sup> day<sup>-1</sup>), proportion of hay intake (%), laying percentage (%), egg mass (g bird<sup>-1</sup> day<sup>-1</sup>), feed conversion and body weight (g).

During the three periods, once a week, all the eggs were gathered and identified. Among these, three eggs were selected from each plot in order to determine the quality of the eggs: egg weight (g), specific gravity, Haugh units, percentage of yolk, shell and albumen (%) and yolk pigmentation.

Statistical analysis was made by means of SAS (2000). Data were subjected to regression analysis, excluding the reference diet to describe the effect of the restriction level upon the variables. Also, mean values were compared using the Dunnett's test (5%)

to verify the effect of each restriction level in relation to the control.

To determine the preference of birds for the hays, the consumption data for each hay in the different restriction levels were evaluated following the factorial model 4 x 3 where the factors were the four restriction levels and three types of hays. And for this analysis we employed the Tukey's test (5%).

## Results and discussion

According to the regression analysis, with increased level of restriction of feed offered to the birds, there was a linear reduction in the feed intake (Table 2). From 5% restriction of the diet, it was observed a significant reduction in the feed intake by the birds. On the other hand, as the restriction level increased, there was a linear increase in the amount of hay ingested daily by the birds during the experimental period (Table 2).

The lower feed intake observed in treatments that used the feed restriction is directly related to the reduction in the amount of feed supplied daily to the birds, resulting in a lower daily intake of nutrients. In this way, the birds tried to meet their nutritional requirements by increasing the intake of hay.

In the assessment of preference of the birds for the used hays (Table 3), no significant interaction was detected between the restriction level and the type of hay offered to the birds. The restriction level also did not influence on the choice of the hay by the hens. Nevertheless, regardless of restriction level, the hens presented lower intake of Tifton hay, preferring the cunhã hay and leucaena leaf meal.

Legumes have higher protein content when compared to grasses, mainly by their high capacity for symbiotic nitrogen fixation and recycling of this substance (CARVALHO; PIRES, 2008). In this way, the preference of the birds for the legume hays is associated with the ability to select the food according to nutritional requirements to

meet the nitrogen demand unmet by the amount of feed supplied.

The regression analysis evidenced a linear reduction in the laying percentage with increasing feed restriction (Table 2). Nevertheless, according to a comparison by the Dunnett's test, the difference was significant in relation to the control only from the 10% restriction level ( $p < 0.05$ ).

According to Costa et al. (2009), during the laying stage, the energy is the most important factor to obtain optimal production rates. In this way, the reduction in laying percentage with the subjection of the birds to a lower feed amount is associated with the reduction in the daily amount of metabolizable energy available to birds.

Based on the feed intake, it was estimated that the hens ingested on average 263, 255, 242, 228 and 215 kcal bird<sup>-1</sup> day<sup>-1</sup>, when the amounts of feed supplied daily were 100, 95, 90, 85, 80 g bird<sup>-1</sup> day<sup>-1</sup>, respectively. These values are lower than those suggested by Rostagno et al. (2005) that recommended the supply of 297 kcal bird<sup>-1</sup> day<sup>-1</sup> for laying hens, at this age.

When evaluating the restriction effect of the energy intake by the reduction in the amount of feed intake by laying hens, De Blas (1991) reported that the egg production of hens fed ad libitum was not significantly different from the obtained for hens subjected to a feed restriction of 5%. Nevertheless, reductions between 8 and 10% promoted a significant drop in the production. According to the author, the more intense is the restriction of energy intake, the greater the negative effect on egg production, so that the laying can be reduced around 1.5%, when reducing 5% in the amount of feed supplied, and can increase of 7 and 28% when reducing the feed supplied in 10 and 20%, respectively. These results are similar to those obtained in the present study, since with the increase in restriction of feed from 5 to 20%, the reduction in the production of eggs was 3.49 to 24.7% in relation to that obtained for the control.

**Table 2.** Performance of laying hens subjected to various levels of feed restriction and supply of hay ad libitum.

| Variables                                                          | Level of feed restriction |        |        |        |        | Mean  | CV (%) |
|--------------------------------------------------------------------|---------------------------|--------|--------|--------|--------|-------|--------|
|                                                                    | 0%                        | 5%     | 10%    | 15%    | 20%    |       |        |
| Feed intake (g bird <sup>-1</sup> day <sup>-1</sup> ) <sup>1</sup> | 97.87                     | 95.00* | 90.00* | 85.00* | 80.00* | 89.58 | 0.38   |
| Hay intake (g bird <sup>-1</sup> day <sup>-1</sup> ) <sup>2</sup>  | -                         | 3.76   | 5.58   | 5.62   | 6.38   | 5.33  | 23.97  |
| Laying (%) <sup>3</sup>                                            | 91.70                     | 88.41  | 81.11* | 78.20* | 68.86* | 81.66 | 5.41   |
| Egg weight (g)                                                     | 61.10                     | 60.78  | 62.10  | 61.94  | 61.71  | 61.53 | 2.70   |
| Egg mass (g bird <sup>-1</sup> day <sup>-1</sup> ) <sup>4</sup>    | 57.30                     | 53.71  | 51.43* | 48.38* | 42.38* | 50.64 | 4.30   |
| Feed conversion                                                    | 1.70                      | 1.77   | 1.75   | 1.76   | 1.91*  | 1.78  | 4.51   |

\*Different from the control by the Dunnett's test (5%). <sup>1</sup>  $\hat{Y} = 100 - 1x, r^2 = 1$ ; <sup>2</sup>  $\hat{Y} = 3.36 + 0.16x, r^2 = 0.39$ ; <sup>3</sup>  $\hat{Y} = 94.53 - 1.23x, r^2 = 0.76$ ; <sup>4</sup>  $\hat{Y} = 58.24 - 0.74x, r^2 = 0.35$ .

**Table 3.** Proportion of the cunhã hay, leucaena leaf meal and tifton hay (%) in relation to the total intake of hay by laying hens according to the feed restriction levels.

| Restriction level (%) | Proportion of the hays (%) |                    |         |
|-----------------------|----------------------------|--------------------|---------|
|                       | Cunhã                      | Leucaena leaf meal | Tifton  |
| 5                     | 34.53                      | 42.25              | 23.22   |
| 10                    | 36.46                      | 38.28              | 25.27   |
| 15                    | 34.15                      | 41.73              | 24.13   |
| 20                    | 30.43                      | 41.79              | 27.77   |
| Mean <sup>1</sup>     | 33.89 a                    | 41.01 a            | 25.10 b |

<sup>1</sup>In the row, mean values followed by distinct lower case letters are different by the Tukey's test (5%).

The egg weight had no change with increasing level of feed restriction ( $p < 0.05$ ). Considering that the protein content of the diet is the main factor affecting the egg weight (LEESON et al., 2001), we calculated the protein intake by the hens of the different treatments. The average intake was 18.15, 17.63, 16.70, 15.77 and 14.85 g of CP bird<sup>-1</sup> day<sup>-1</sup>, for the hens subjected to the ingestion of 100, 95, 90, 85, 80 g bird<sup>-1</sup> day<sup>-1</sup>, respectively. The values of CP daily intake of the birds subjected to 0, 5 and 10% of feed restriction were close to those recommended by the NRC (1994), which is 16.33 g of CP bird<sup>-1</sup> day<sup>-1</sup> for laying hens. However, the birds subjected to restriction of 15 and 20% have ingested an amount of CP lower than recommended.

Although in the present study it was noticed a reduction in CP daily intake by the hens, unlike reported by some authors, there was no significant variation in egg weight. This was due to the reduction in egg production with increasing restriction levels, since the CP requirement decreases; then the CP intake from hens subjected to the highest restraint was enough to maintain the egg weight. According to Sakomura et al. (2002), the production level of laying hens and the egg weight depend on the protein intake. In this way, variations in the production level directly affect the daily intake of CP by the birds and, with a reduction in the production level, there is necessarily reduction in the requirements for crude protein.

In agreement with De Blas (1991), in relation to the effect of restricting energy intake on the egg weight, the studies had pointed out that the restriction of up to 6% in the amount of feed supplied did not significantly affected the egg weight. However, higher restriction levels between 8 and 10% promoted significant reduction in egg weight.

The egg mass decreased linearly with increasing levels of feed restriction (Table 2). Meantime the comparison between the means by the Dunnett's test (5%) showed that only from the 10% of restriction, the egg mass had value significantly lower than the control. Taking into consideration

that the egg mass is calculated by multiplying the number of eggs produced by the average egg weight (g), the reduction in the laying percentage was responsible for the reduction in the egg mass, since the egg weight did not change.

The feed conversion (Table 2) worsened linearly with increasing feed restriction. This result is associated with the reduction in egg mass with increasing restriction level. Nevertheless, the Dunnett's test (5%) evidenced that only with 20%-restriction, the feed conversion differed significantly from the obtained for the hens fed with 100 g of feed bird<sup>-1</sup> day<sup>-1</sup>.

The variables, percentage of yolk, albumen and shell, specific gravity, Haugh units and yolk color (Table 4) were not influenced significantly by the restriction levels of the laying diet, according to regression analysis.

**Table 4.** Characteristics of eggs of laying hens submitted to various levels of feed restriction with supply of hay ad libitum.

| Variables        | Level of feed restriction |       |       |       |        | Mean  | CV (%) |
|------------------|---------------------------|-------|-------|-------|--------|-------|--------|
|                  | 0%                        | 5%    | 10%   | 15%   | 20%    |       |        |
| Yolk (%)         | 24.20                     | 24.30 | 23.63 | 23.96 | 24.22  | 24.03 | 2.82   |
| Albumen (%)      | 66.40                     | 66.38 | 67.22 | 66.90 | 66.61  | 66.77 | 1.10   |
| Shell (%)        | 9.40                      | 9.32  | 9.15  | 9.13  | 9.18   | 9.20  | 2.77   |
| Specific gravity | 1.078                     | 1.079 | 1.079 | 1.074 | 1.094  | 1.082 | 1.50   |
| Haugh units      | 80.11                     | 84.07 | 84.00 | 84.54 | 84.41  | 84.25 | 3.78   |
| Yolk color       | 8.93                      | 9.30  | 9.38  | 9.36  | 9.66 * | 9.42  | 2.88   |

\*Different from the control by the Dunnett's test (5%).

When comparing the means using the Dunnett's test (5%), only the yolk color was significantly different between treatments. The results showed that the eggs from hens subjected to 20% restriction presented darker yolks than the control hens, which received no hay. This is related to the higher intake of carotenoid pigments by the birds, since the intake of hay (Table 3) was greater at this restriction level.

The quality of the egg shell depends on the mineral intake and primarily of calcium and phosphorus by the laying hens. In this way, the reduction in the amount of feed supplied daily could lead to reduced intake of minerals and consequently worsen the quality of the egg shell. Meantime, in the present study, it was not observed significant difference for the specific gravity of eggs from the different treatments nor for the percentage of shell (Table 4). On the other hand, the hays supplied to the birds are rich in calcium and phosphorus, since the leucaena leaf meal presents 2.18% of calcium and 0.20% of phosphorus, and the cunhã hay has 0.28% of calcium and 0.18% of phosphorus, according to Valadares Filho et al. (2006), which contributes to increase the intake of these minerals by the birds.

The Table 5 lists the data of change in the weight of hens during the experimental period. At the end of the experiment, the birds subjected to different restriction levels presented weight significantly lower in comparison with the control, without restriction ( $p > 0.05$ ).

**Table 5.** Average initial body weight (IBW), final body weight (FBW) and body weight change (BWC) submitted to various levels of feed restriction with supply of hay ad libitum.

| Restriction level (%) | IBW (g) | FBW (g) | BWC (g bird <sup>-1</sup> ) <sup>1</sup> | BWC (g bird <sup>-1</sup> day <sup>-1</sup> ) <sup>2</sup> |
|-----------------------|---------|---------|------------------------------------------|------------------------------------------------------------|
| 0                     | 1,760   | 1,792   | 28.67                                    | 0.45                                                       |
| 5                     | 1,733   | 1,730*  | - 3.33                                   | - 0.05                                                     |
| 10                    | 1,733   | 1,652*  | - 67.87*                                 | - 1.08*                                                    |
| 15                    | 1,730   | 1,655*  | - 74.67*                                 | - 1.19*                                                    |
| 20                    | 1,720   | 1,630*  | - 103.33*                                | - 1.64*                                                    |
| Mean value            | 1,736   | 1,692   | - 44.11                                  | - 0.70                                                     |
| CV (%)                | 2.01    | 2.00    | - 101.29                                 | - 101.35                                                   |

\*Different from the control by the Dunnett's test (5%). <sup>1</sup> $\bar{Y} = 23.26 - 6.87x$ ,  $r^2 = 0.56$ ; <sup>2</sup> $\bar{Y} = 0.37 - 0.11x$ ,  $r^2 = 0.56$ .

Hens fed without dietary restriction gained weight, and those subjected to feed restriction presented linear reduction of the mean weight during the experiment.

Although the birds subjected to 5% feed restriction had presented reduction in body weight, there was no significant difference in relation to the weight change of control hens, according to Dunnett's test ( $p > 0.05$ ). However, for the other levels of restriction, the weight reduction was significantly greater in relation to the control, using the same test.

The weight loss is associated with the reduction in daily intake of energy by the hens. According to the NRC (1994) and Rostagno et al. (2005), the laying hens should receive energy and nutrients able to meet the requirements for maintenance, egg production, and weight gain that can range from 0 to 2 g bird<sup>-1</sup> day<sup>-1</sup>. This did not occur for the birds subjected to different levels of dietary restriction.

Our results evidenced that, the hens under no restriction have consumed enough energy and nutrients for the maintenance, egg production, and daily weight gain of 0.45 g bird<sup>-1</sup> (Table 5). However, birds under feed restriction from 10% had significant weight loss, and drop in egg production, when compared to the control (Table 2), clearly showing a deficit in nutrient intake by the hens at this restriction level.

Considering that the weight and characteristics of egg quality were not affected by the dietary restriction, the main problem when reducing the amount of feed supplied for the hens was the energy deficiency to maintain the egg production and body weight. Thus opting to use hens with better genetic quality for eggs production in semi-intensive system,

it should be ensured the intake of enough feed to promote the intake of at least 255 kcal bird<sup>-1</sup> day<sup>-1</sup>.

According to De Blas (1991), in eggs production the dietary restriction can be used at an economic situation where the feeding cost is high, and the egg price is low. In the case of free-ranger egg production, the introduction of hay in the feeding of laying hens reduces the amount of feed supplied, and improves the yolk color, which is the differential of quality more important for this type of product. Nevertheless, the producer should not forget that the remuneration for the activity will take place by selling the higher number of eggs, since although these eggs has differentiated price in relation to other commercial eggs, this is fixed for each category. Therefore, as shown in the present study, the problems related to the greater reduction in the concentrate supplied for laying hens can not be solved with the supply of forage for the birds.

## Conclusion

The laying hens can be submitted to 5% feed restriction with the supply of hay ad libitum, without significant changes on the performance of the hens and egg quality. The birds preferred the legume hay instead of grass hay, providing darker yolks, justifying the employment of this technique in alternative poultry farming.

## References

- BUCHANAN, N. P.; HOTT, J. M.; KIMBLER, L. B.; MORITZ, J. S. Nutrient Composition and digestibility of organic broiler diets and pasture forages. **Journal of Applied Poultry Research**, v. 16, n. 1, p. 13-21, 2007.
- CARVALHO, G. G. P.; PIRES, A. J. V. Leguminosas tropicais herbáceas em associação com pastagens. **Archivos de Zootecnia**, v. 57, n. 1, p. 103-113, 2008.
- COSTA, F. G. P.; COSTA, J. S.; GOULARTE, C. C.; LIMA, D. F. F.; NETO, L. R. C.; QUIRINO, B. J. S. Metabolizable energy levels for semi-heavy laying hens at the second production cycle. **Revista Brasileira de Zootecnia**, v. 38, n. 6, p. 2247-2254, 2009.
- DE BLAS, C. B. Necesidades energéticas de las gallinas ponedoras. In: DE BLAS, C. B.; MATEOS, G. G. (Ed.). **Nutrición y alimentación de gallinas ponedoras**. Madrid: Mundi Prensa, 1991. p. 145-157.
- EURIBRID HISEX. **Manual da linhagem Hisex brown**: EURIBRID HISEX, 2001.
- LEESON, S.; SUMMERS, J. D.; CASTON, L. J. Response of layers to low nutrient density diets. **Journal of Applied Poultry Research**, v. 10, n. 1, p. 46-52, 2001.
- NRC-Nacional Research Council. **Nutrients requirements of poultry**. Washington D.C.: NRC, 1994.
- PATERSON, R. T.; ROOTHAERT, R. L.; KIRUIRO, E. The feeding of leaf meal of *Calliandra calothyrsus* to laying

hens. **Tropical Animal Health and Production**, v. 32, n. 1, p. 51-61, 2000.

ROSTAGNO, H. S.; ALBINO, L. F. T.; DONZELE, J. L.; GOMES, P. C.; OLIVEIRA, R. F.; LOPES, D. C.; FERREIRA, A. S.; BARRETO, S. L. T. **Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais**. 2. ed. Viçosa: UFV, 2005.

SAKOMURA, N. K.; BASAGLIA, R.; RESENDE, K. T. Modelo para determinar as exigências de proteína para poedeiras. **Revista Brasileira de Zootecnia**, v. 31, n. 6, p. 2247-2254, 2002.

SAS-Statistical Analysis System. **User's guide**. Version 6, 12th ed. Cary: SAS Institute Inc., 2000.

SOUZA, N. A.; OLIVEIRA, J. F.; HOLANDA, J. S.; CHAGAS, M. C. M.; FILHO, J. A. **Ave caipira**. Natal: Emparn, 2008.

VALADARES FILHO, S. C.; CAPPELLE, E. R.; ROCHA JÚNIOR, V. R.; MAGALHÃES, K. A. **Tabelas brasileiras de composição de alimentos para bovinos**. 2. ed. Viçosa: UFV, 2006.

*Received on February 7, 2011.*

*Accepted on June 15, 2011.*

License information: This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.