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# *Laying Performance and Egg Quality of Japanese Quails Fed Diets Containing Castor Meal and Enzyme Complex*

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## ABSTRACT

The objective of this study was to evaluate the effect of diets formulated with corn plus soybean meal (CSM) or with 21% autoclaved castor meal (ACM), with the addition of two enzyme complexes (EC1 and EC2), on the performance and egg quality of laying quail. Two hundred and sixteen quails were selected by egg production and weight uniformity and distributed in a completely randomized design with six treatments (in a 2 × 3 cross-factorial arrangement) and six replicates with six birds each. Three CSM and three ACM diets supplemented withEC1, EC2, or unsupplemented were established. The trial lasted three cycles of 21 days. Feed intake, laying rate, egg mass, feed conversion per egg mass, and feed conversion per dozen eggs did not differ. The use of ACM diet reduced egg (EW), yolk (YW), and eggshell (SW) weights, egg specific gravity and increased yolk color. However, EW and YW were similar among quails fed diets containing CSM and ACM when supplemented with CE1.The use of enzyme complex containing xylanase, β-glucanase, and phytase is recommended when 21% autoclaved castor mealis included in the diet of laying quails.

## INTRODUCTION

With the development of the poultry industry, major advances have been achieved, providing alternatives to make feed compounding more efficient and economical. Enzymes have an effect on diet cost reduction and contribute to reducing antinutritional effects of ingredients, improving the diet digestibility and poultry performance (Olukosi *et al*., 2007), especially when alternative feedstuffs, such as castor (*Ricinus communis* L.), are used in the feed.

Castor (*Ricinus communis* L.) is one of the most traditional crops grown in the Brazilian northeast semi-arid region. After being pressed, castor seeds generate the castor cake, a high-protein and high-fiber solid extract residue. Its high protein content (30.9%, according to Matos Júnior *et al*. (2011) renders it an attractive alternative for animal feed, but the presence of toxic and allergenic compounds, such as ricin and2S albumins, have made its use impractical on a large commercial scale (Severino *et al*., 2012). However, according to Anandan *et al*. (2005), the heat and pressing treatment of the meal associated with chemical agents such as CaO or $Ca(OH)_2$ may inactivate ricin and the allergen compound CB-1A, identified by Youle & Huang (1978) as 2S albumins, in beans and castor seeds.

Defatted castor seed meal has a high concentration of insoluble fiber, which can reduce the nutrient digestibility as well as the performance of poultry (Santos *et al*., 2015). Based on Brazilian literature castor cake, expected average composition is 60% total carbohydrates, 10% non-fibrous carbohydrates, 50% neutral detergent fiber, 40% acid

detergent fiber, and 25% lignin. As stated by Costa *et al*. (2004), the insoluble fiber percentage in the castor cake and defatted castor meal can vary between 43 and 51%, given the processing variability and different castor varieties. The insoluble-fiber fraction has low digestibility in poultry, increases endogenous nutrient loss, and simultaneously reduces the presence of potentially metabolizable nutrients in the diet, thereby preventing the action of enzymes on the digest and reducing the energy concentration of the feed. The effects of fiber are associated with viscosity, which can increase as a result of the non-starch polysaccharide content, especially its β-glucan and arabinoxylan fractions (Tavernari *et al*., 2008). Increases in viscosity may reduce nutrient digestion in the small intestine (Jaroni *et al*., 1999). According to Chotinsky *et al*. (2015), the exact effects of viscosity have not been established, but possible mechanisms include reduced rates of diffusion of endogenous enzymes and nutritional substrates.

However, the use of exogenous enzymes can reduce the viscosity of the digesta (Bharathidhasan *et al*., 2009) as well as improve the nutrient utilization (Jaroni *et al*., 1999).

This study was conducted to evaluate the effect of diets formulated with corn plus soybean meal or with 21% autoclaved castor meal, plus the addition of two enzyme complexes, on performance and egg quality of laying quails.

## MATERIAL AND METHODS

The experiment was conducted in Recife, Brazil 8°03'28" S latitude and 34°52'58" W longitude, at 9m (asl). Procedures involving animals were performed according to the Institutional Committee on Animal Use (license no. 043/2012). Two hundred and sixteen quails of 39 days of age were housed in 36 galvanized-wire cages (33 × 25 × 20cm) in a room with temperature control set at 22°C. After reaching peak egg production, the selected quails were distributed in a completely randomized design with six treatments, six replicates, and six birds per experimental unit. The selection and distribution criteria were uniformity in body weight and production. At the beginning of the experiment, quails had an average weight of 160.1g and egg laying rate above 90%. The trial period lasted 63 days (21-day cycles) and quails received 17 h of light per day. Temperature was monitored once a day, using maximum and minimum thermometers. The quails were fed a mash diet twice daily, and water was provided *ad libitum*.

Castor meal was provided by the Biodiesel Unit located in Pesqueira-PE, Brazil. The castor meal was homogenized with 6% CaO; subsequently, water was added at a 1:1 ratio by weight with homogenization until forming uniform wet mixture. This mixture was placed in vats (to a height of 25cm) that were placed on the autoclave. The mixture was autoclaved at a pressure of 1.23kgf $cm^{-2}$, at 104 °C, for 90 min. Each of the vats placed in the autoclave had its upper part open and unobstructed, allowing the exit of steam. After processing, the autoclaved castor meal was sun-dried for later storage and milling. The procedures were adapted from recommendations of Anandan *et al*. (2005) and Cobianchi *et al*. (2012).

Treatments were established as a cross-factorial arrangement, as follows: corn- and soybean meal-based diet (CSM); CSM plus enzyme complex EC1; CSM plus enzyme complex EC2; 21% autoclaved castor meal (ACM); ACM plus EC1 (ACMEC1); and ACM plus EC2 (ACMEC2). The chemical composition of the ingredients used in the diets (corn, soybean meal, and autoclaved castor meal) was analyzed (Table 1).

Enzyme complexes 1 and 2 were included in the amounts of 50and 75$gt^{-1}$, respectively, according to the recommendation of the manufacturers. Enzyme complex 1 had the following enzyme content: 160U xylanase (EC 3.2.1.8), 215U beta-glucanase (EC 3.2.1.6), and 500FTU phytase (EC 3.1.3.26) per kilogram of feed. Enzyme complex 2 included the following enzymes: 300U xylanase (EC 3.2.1.8), 4000U protease (EC 3.4.21.62), and 400 α-amylase (EC 3.2.1.1) per kilogram of feed.

Because both EC are active in different substrates, given their different compositions, we evaluated their effects on the measured parameters so as not to individualize the isolated effect of the present enzymes. In the formulation of the diets (Table 2), we adopted the recommendations of nutritional requirements described by Silva & Costa (2009), while the ingredient composition was based on Rostagno *et al*. (2011). The level of autoclaved castor meal was established in an experiment performed previously in which we identified that laying quail performance declined if levels equal to or greater than 21% were used.

Diets were formulated using a single nutritional matrix, regardless of EC addition. This formulation procedure is named "over the top" (Scheideler *et al*., 2005), and we used it in this experiment to determine whether EC has the ability to repair possible negative effects from the use of ACM.

For performance evaluation, eggs were counted and weighed daily and feed leftovers and average egg weight were quantified weekly to determine egg production per day (laying rate, %), feed intake (FI, g day$^{-1}$), egg weight (EW, g), egg mass (EM, g day$^{-1}$), feed conversion per egg mass (FCEM, g of egg g of diet$^{-1}$), and feed conversion per dozen eggs (FCDZ, g of diet 12 eggs$^{-1}$).

Egg quality was determined by measuring EW; eggs specific gravity (ESG); albumen height (mm); Haugh unit (HU); weights of yolk (YW, g), eggshell weight (SW, g), and albumen weight (AW, g); percentages of yolk, albumen, and shell; shell thickness (ST, mm); and yolk color (YC, DSM/Roche Yolk fan).

Eggs were weighed daily and a representative sample of average weight of eggs, per experimental unit, was obtained from the last three days of each cycle to determine EW. After 63 days, mean values from 18 eggs per experimental unit were generated (2 eggs day$^{-1}$, 3 days cycle$^{-1}$, three cycles). Specific gravity was measured by immersing the egg in saline solutions; for this step, ten solutions were prepared in labeled cans with densities ranging from 1.050 to 1.100g cm$^{-3}$, with a gradual increase of 0.005g cm$^{-3}$, using distilled water at an average temperature of 22°C and salt (NaCl).

**Table 1 -** Chemical composition of ingredients used in diets and calculated percentage composition of experimental diets according to diet type with or without autoclaved castor meal and addition of enzyme complexes.

| Component | Ingredient (g kg$^{-1}$ as fed) | | |
|---|---|---|---|
| | Corn (grain) | Soybean meal | autoclaved castor meal |
| Crude protein | 72.90 | 449.80 | 279.20 |
| AMEn (Kcal kg$^{-1}$) | 3440 | 2330 | 2267 |
| Crude fiber | 17.3 | 53.70 | 276.20 |
| Ash | 12.7 | 58.30 | 58.50 |
| Crude fat | 36.5 | 16.60 | 96.80 |
| Calcium | 0.30 | 2.40 | 49.50 |
| Total phosphorus | 2.50 | 5.60 | 8.90 |
| Available phosphorus | 0.60 | 2.20 | 2.80 |
| Total arginine | 3.5 | 33.20 | 22.90 |
| Total histidine | 2.10 | 11.90 | 4.00 |
| Total isoleucine | 2.40 | 21.50 | 12.50 |
| Total leucine | 8.70 | 34.80 | 19.10 |
| Total methionine + cysteine | 3.00 | 6.10 | 7.60 |
| Total methionine | 1.50 | 6.10 | 4.30 |
| Total lysine | 2.10 | 27.70 | 5.60 |
| Total threonine | 2.90 | 18.00 | 0.80 |
| Total tryptophan | 0.50 | 6.40 | 4.10 |
| Total valine | 3.40 | 22.30 | 12.70 |

Haugh unit was established by the following procedure: after identification for EW determination, eggs were broken individually and contents were placed on a flat glass plate surface without inclination (on a stand with adjustable legs for leveling)to determine albumen height, which was measured to the nearest tenth of a millimeter using a digital caliper. Egg weight and albumen height (h, mm) values were used in the formula HU=100 log (h + 7.57 – 1.7 EW$^{0.37}$), according to Zita *et al*. (2013). To determine the percentages of shell and yolk, yolks were separated and weighed manually and shells were subsequently dried in a forced-air oven at 105°C for 24 h and weighed. Albumen weight was obtained as the difference between EW with SW and YW.

Shell thickness was assessed including membranes, using the same eggs broken to determine albumen quality. Shells were washed and then allowed to dry overnight at room temperature. After drying, eggshell thickness measurements were carried out on two different sites in the central cross-sectional eggshell area using a digital caliper. For colorimetry, two evaluators with normal vision used the DSM/Roche® color fan (yolk fan) in which YC was compared with the color scale (ranging between one and fifteen) of the fan.

The main effect of factors and their interaction were assessed by analysis of variance. Means were compared by applying two Dunnett's test (at 5% probability) using as a reference either CSM diet (Dunnett's test 1) or ACM diet (Dunnett's test 2). Dunnett's test 1 allows for a comparison of all other treatments with CSM, while Dunnett's test 2 allows for a comparison of ACMEC1 and ACMEC2 with ACM. Statistical analyses were performed using SAS (Statistical Analysis System, version 9.4).

**Table 2 –** Composition and calculated analysis of experimental layer quail diets formulated with corn plus soybean meal or 21% autoclaved castor meal, with and without enzyme complex (EC).

| | Experimental diet | | | | | |
|---|---|---|---|---|---|---|
| | Corn soybean meal | | | 21% autoclaved castor meal | | |
| | Without EC | EC1 | EC2 | Without EC | EC1 | EC2 |
| Ingredient (g $kg^{-1}$ as fed) | | | | | | |
| Corn | 453.220 | 452.650 | 452.360 | 388.400 | 387.830 | 388.240 |
| Soybean meal (45%) | 413.810 | 413.980 | 414.060 | 287.100 | 287.270 | 287.130 |
| Autoclaved castor meal | 0.0000 | 0.0000 | 0.0000 | 210.000 | 210.000 | 210.000 |
| Limestone | 69.250 | 69.250 | 69.250 | 43.970 | 43.970 | 43.970 |
| Soybean oil | 37.220 | 37.570 | 37.750 | 42.020 | 42.370 | 42.070 |
| Dicalcium phosphate | 15.230 | 15.230 | 15.230 | 13.770 | 13.770 | 13.770 |
| Vitamin supplement[1] | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 | 1.800 |
| Mineral supplement[1] | 1.200 | 1.200 | 1.200 | 1.200 | 1.200 | 1.200 |
| Salt (NaCl) | 5.860 | 5.860 | 5.860 | 5.880 | 5.880 | 5.880 |
| DL-methionine (99%) | 1.410 | 1.410 | 1.410 | 1.610 | 1.610 | 1.610 |
| Choline chloride (60%) | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| L-lysine HCl (78%) | 0.000 | 0.000 | 0.000 | 2.620 | 2.620 | 2.620 |
| L-threonine (98.5%) | 0.000 | 0.000 | 0.000 | 0.630 | 0.630 | 0.630 |
| Enzyme complex 1[2] | 0.000 | 0.050 | 0.000 | 0.000 | 0.050 | 0.000 |
| Enzyme complex 2[3] | 0.000 | 0.000 | 0.075 | 0.000 | 0.000 | 0.075 |
| | Calculated composition (g $kg^{-1}$ as fed) | | | | | |
| AMEn (Kcal $kg^{-1}$) | 2850 | 2850 | 2850 | 2850 | 2850 | 2850 |
| Calculated crude protein | 220.000 | 220.000 | 220.000 | 220.000 | 220.000 | 220.000 |
| Analyzed crude protein | 208.100 | 209.800 | 211.300 | 196.400 | 206.700 | 207.200 |
| Crude fiber | 30.060 | 30.050 | 30.050 | 80.350 | 80.340 | 80.350 |
| Fat | 60.250 | 60.570 | 60.730 | 79.610 | 79.920 | 79.650 |
| Calcium | 31.500 | 31.500 | 31.500 | 31.500 | 31.500 | 31.500 |
| Available phosphorus | 4.000 | 4.000 | 4.000 | 4.000 | 4.000 | 4.000 |
| Total lysine | 12.410 | 12.410 | 12.410 | 12.000 | 12.000 | 12.000 |
| Total methionine + cysteine | 8.010 | 8.010 | 8.010 | 8.000 | 8.000 | 8.000 |
| Total methionine | 4.600 | 4.600 | 4.600 | 4.830 | 4.830 | 4.830 |
| Total threonine | 8.760 | 8.760 | 8.760 | 8.600 | 8.600 | 8.600 |
| Total leucine | 18.340 | 18.340 | 18.340 | 17.380 | 17.380 | 17.380 |
| Total tryptophan | 2.870 | 2.870 | 2.870 | 2.890 | 2.890 | 2.890 |
| Sodium | 2.500 | 2.50 | 2.500 | 2.500 | 2.500 | 2.500 |

AMEn - apparent metabolizable energy corrected for nitrogen.[1]Provides per kg of product: Fe - 50,000 mg; Co - 200 mg; Cu - 8,500 mg; Mn - 75,000 mg; Zn - 70,000 mg; Se - 250 mg; I - 1,500 mg; folic acid - 500 mg; pantothenic acid - 13.5 g; niacin - 30 g; vit. A - 10,000,000 IU; vit. $D_3$ -2,000,000 IU; vit. $K_3$ - 4,000 mg; vit. $B_2$- 5,000 mg; vit. $B_6$ - 2,000 mg; $B_{12}$ - 10,000 µg; vit. E - 20,000 mg. [2]Minimal activity provided per gram of EC1: EC 3.2.1.8 - 3,200 U; EC 3.2.1.6 - 4,300 U; EC 3.1.3.26 - 10,000 FTU. [3]Minimal activity provided per gram of EC2: EC 3.2.1.8 - 1,500 U; EC 3.4.21.62 - 20,000 U; EC 3.2.1.1 - 2,000 U.

## RESULTS

During the trial period, the average recorded temperature was 27.4 °C, with a minimum of 24.8 °C and a maximum of 30.0 °C. Average relative humidity was 68.3%.

The results are shows in Table 3 and 4. Most parameters showed no significant difference ($p$>0.05), and the following fit into this condition: FI, laying rate, EM, FCEM, FCDZ, ST, HU, AW, and percentages of yolk, albumen, and shell.

Significant effects were observed ($p$<0.05) for EW, YW, SG, YC, and SW, and these effects resulted from the use of diets with autoclaved castor meal, compared with the CSM diet, by Dunnett's test. Specific gravity was greater in eggs produced by quails receiving CSM diets as compared with eggs from quails fed ACM diets, conversely to YC results.

Shell weight differed significantly (P=0.0015) as affected by diet formulation. Because CaO was used in the castor meal processing, the amount of calcium added via limestone in ACM diets was reduced, and a reduction of 7% was observed in the SW of quail fed ACM diets.

The use of EC had no effect ($p$>0.05) on the evaluated parameters, and there was also no interaction with diet type ($p$>0.05). Enzyme complexes failed to influence some of the effects provided with the use of ACM, but this applies to ESG, YC, and SW.

**Table 3 –** Means (±standard deviation) for performance laying quails fed diets containing corn and soybean meal (CSM) or containing 21% autoclaved castor meal, with or without enzyme complex (EC), descriptive probability level for Dunnett's mean tests of significant parameters, and description of the variance analysis.

| | Corn soybean meal | | | 21% autoclaved castor meal | | |
|---|---|---|---|---|---|---|
| | Without EC | EC1 | EC2 | Without EC | EC1 | EC2 |
| FI (g day$^{-1}$) | 26.81±0.36 | 26.78±0.23 | 26.84±0.49 | 26.57±0.48 | 27.02±0.53 | 26.08±0.13 |
| Laying rate (%) | 88.04±2.45 | 90.18±2.40 | 90.59±1.07 | 88.75±3.34 | 91.14±1.52 | 90.21±1.87 |
| EW (g) | 10.99a±0.12 | 10.80±0.18 | 10.74±0.13 | 10.42b±0.13 | 10.61±0.11 | 10.28b±0.04 |
| EM (g day$^{-1}$) | 9.67±0.27 | 9.75±0.35 | 9.73±0.20 | 9.24±0.31 | 9.67±0.35 | 9.27±0.22 |
| FCEM (g g$^{-1}$) | 2.78±0.09 | 2.77±0.12 | 2.77±0.08 | 2.89±0.11 | 2.80±0.08 | 2.82±0.06 |
| FCDZ (g dz$^{-1}$) | 367.1±12.2 | 357.9±11.8 | 355.9±8.9 | 361.8±15.2 | 356.4±10.2 | 347.4±6.22 |
| Descriptive probability level (P) for means using Dunnett's test 1 or Dunnett's test 2 | | | | | | |
| EW[1] (g) | - | 0.6729 | 0.4287 | 0.0089 | 0.1178 | 0.0012 |
| EW[2] (g) | - | - | - | - | 0.6657 | 0.8830 |
| Analysis of variance (P) | | | | | | |
| | CV (%) | | Enzyme complex | Diet | | Enzyme complex × Diet |
| AFI (g day$^{-1}$) | 3.65 | | 0.5468 | 0.4360 | | 0.4580 |
| Laying rate (%) | 6.08 | | 0.5754 | 0.8201 | | 0.9557 |
| EW (g) | 2.88 | | 0.1838 | 0.0003 | | 0.2640 |
| EM (g day$^{-1}$) | 6.65 | | 0.6281 | 0.1638 | | 0.7474 |
| FCEM (g g$^{-1}$) | 8.18 | | 0.8403 | 0.4513 | | 0.9211 |
| FCDZ (g dz$^{-1}$) | 7.61 | | 0.5663 | 0.6064 | | 0.9574 |

Means followed by lowercase letters in the same row differ ($p$<0.05) by Dunnett's test using CSM diet as control. CV - coefficient of variation. AFI - average feed intake; EW - egg weight; EM - egg mass; FCEM - feed conversion per egg mass; FCDZ - feed conversion per dozen eggs. [2]Minimal activity provided per gram of EC1: EC 3.2.1.8 - 3,200 U; EC 3.2.1.6 - 4,300 U; EC 3.1.3.26 - 10,000 FTU. [3]Minimal activity provided per gram of EC2: EC 3.2.1.8 - 1,500 U; EC 3.4.21.62 - 20,000 U; EC 3.2.1.1 - 2,000 U.

**Table 4 –** Means (±standard deviation) for egg quality of quails fed diets containing corn and soybean meal (CSM) or containing 21% autoclaved castor meal, with or without enzyme complex (EC), descriptive probability level for Dunnett's mean tests of significant parameters, and description of the variance analysis.

| | Corn soybean meal | | | 21% autoclaved castor meal | | |
|---|---|---|---|---|---|---|
| | Without EC | EC1 | EC2 | Without EC | EC1 | EC2 |
| SG | 1.074a±0.001 | 1.074±0.001 | 1.077±0.001 | 1.071b±0.001 | 1.071b±0.001 | 1.072b±0.001 |
| ST (mm) | 0.130±0.002 | 0.133±0.002 | 0.133±0.002 | 0.132±0.002 | 0.131±0.003 | 0.131±0.002 |
| HU | 87.70±0.20 | 87.90±0.21 | 88.07±0.20 | 88.21±0.17 | 88.17±0.21 | 88.04±0.20 |
| YC | 4.25a±0.04 | 4.26±0.06 | 4.31±0.05 | 4.52b±0.04 | 4.44b±0.03 | 4.51b±0.05 |
| YW (g) | 3.89a±0.08 | 3.79±0.06 | 3.76±0.06 | 3.61b±0.07 | 3.68±0.05 | 3.58b±0.04 |
| AW (g) | 6.27±0.07 | 6.18±0.13 | 6.13±0.14 | 6.05±0.11 | 6.18±0.07 | 5.93±0.07 |
| SW (g) | 0.88a±0.02 | 0.87±0.03 | 0.87±0.03 | 0.81b±0.02 | 0.81b±0.01 | 0.82b±0.02 |
| Yolk (%) | 35.23±0.50 | 34.97±0.32 | 34.92±0.50 | 34.52±0.62 | 34.52±0.42 | 34.69±0.46 |
| Albumen (%) | 56.78±0.67 | 57.04±0.28 | 56.95±0.67 | 57.74±0.70 | 57.91±0.47 | 57.40±0.50 |
| Eggshell (%) | 7.99±0.19 | 7.99±0.13 | 8.06±0.26 | 7.75±0.19 | 7.57±0.07 | 7.92±0.14 |
| Descriptive probability level (P) for means using Dunnett's test 1 or Dunnett's test 2 | | | | | | |
| Yolk[1] (g) | - | 0.7037 | 0.4747 | 0.0237 | 0.1242 | 0.0105 |
| Yolk[2] (g) | - | - | - - | - | 0.8991 | 0.9965 |
| | Analysis of variance (P) | | | | | |
| | CV (%) | | Enzyme complex | Diet | | Enzyme complex × Diet |
| SG | 0.16 | | 0.9035 | <0.0001 | | 0.9898 |
| ST (mm) | 4.21 | | 0.8356 | 0.7794 | | 0.4691 |
| HU | 0.53 | | 0.8425 | 0.1048 | | 0.3500 |
| YC | 2.50 | | 0.3330 | <0.0001 | | 0.6027 |
| YW (g) | 4.00 | | 0.4166 | 0.0017 | | 0.4218 |
| AW (g) | 4.12 | | 0.2227 | 0.0641 | | 0.4170 |
| SW (g) | 6.22 | | 0.9068 | 0.0015 | | 0.8732 |
| Yolk (%) | 3.63 | | 0.9629 | 0.2326 | | 0.8712 |
| Albumen (%) | 2.43 | | 0.8528 | 0.1077 | | 0.8867 |
| Eggshell (%) | 5.38 | | 0.4338 | 0.0505 | | 0.6965 |

Means followed by lowercase letters in the same row differ ($p$<0.05) by Dunnett's test using CSM diet as control. CV - coefficient of variation. SG - specific gravity; ST - shell thickness; HU - Haugh unit; YC - yolk color; YW - yolk weight; AW- albumen weight; SW - eggshell weight. [2]Minimal activity provided per gram of EC1: EC 3.2.1.8 - 3,200 U; EC 3.2.1.6 - 4,300 U; EC 3.1.3.26 - 10,000 FTU. [3]Minimal activity provided per gram of EC2: EC 3.2.1.8 - 1,500 U; EC 3.4.21.62 - 20,000 U; EC 3.2.1.1 - 2,000 U.

## DISCUSSION

The observed temperatures are above thermal comfort range quoted by Rosa *et al*. (2011). However, cage density (137.5cm$^2$ bird$^{-1}$) combined with temperature did not affect performance. Coefficients of variation were below values reported by Leal *et al*. (2014).

Although it is considered a fibrous food, 21% autoclaved castor meal did not influence the evaluated parameters. A steady FI is the main parameter measured in animal trials to confirm adequate processing of castor cake and meal (Bueno *et al*., 2014). The mean performance values are comparable to those reported by Barreto *et al*. (2007) for the initial laying phase; however, they differ from those reported by Hemid *et al*. (2010), who evaluated the production of quails at the same age.

The parameters AFI, EM, FCEM, and FCDZ corroborate the data reported by Araujo *et al*. (2008), who did not find significant effects ($p$>0.05) on the evaluated variables using wheat meal and an enzyme complex in the diet of laying hens. However, the use of enzymatic complex in the study of Araujo *et al*. (2008) increased EW, while in the present study a slight decrease was detected in EW in comparing the 21% autoclaved castor meal diet and ACM plus EC2 in relation to CSM diet. This might have been because the diets with 21% autoclaved castor meal have a high crude fiber content (80.350 g kg$^{-1}$ as fed) in comparison with CSM diet (30.060 g kg$^{-1}$ as fed). According to Costa *et al*. (2004), the insoluble-fiber fraction has low digestibility in poultry, increases endogenous nutrient loss, and simultaneously reduces the presence of potentially metabolizable nutrients in the diet. The fibrous fraction (non-starch polysaccharide) may have promoted the increased viscosity in the digestive tract, which, according to Jaroni *et al*. (1999), may have reduced the digestibility of the nutrients.

Yolk, albumen, and shell percentages were close to those cited by Tolik *et al*. (2014), and the average ST (0.132mm) was 15% lower than that reported by Barreto *et al*. (2007) but within the range of 0.130 to 0.280mm stated by Genchev (2012).

With inclusion of autoclaved castor meal in the diets, a 10.2% relative increase in oil addition in these diets was necessary, which may be partially the cause of increased YC. However, the main influence may be the black color of castor seed coat in variety BRS Nordestina used in this experiment and possibly the presence of higher carotene concentration when compared with CSM diets. Sultana *et al*. (2007) stated that there may be effects on shell quality for different sources of calcium. Additionally, the main effect of SW and ESG reduction in eggs from quails subjected to ACM is assumed to be due to partial unavailability of calcium from CaO, which may have reacted with castor meal during autoclaving.

Santos *et al*. (2015) evaluated a differently processed castor seed meal at the levels of 0, 5, 10, 15, and 20% and also found a decrease in EW and YW at the inclusion level of 20% when compared with CSM diet. However, in the present trial, Dunnett's test 1 (Table 3) revealed that values for ACMEC1 diet did not differ from those observed for CSM. The same effects detected for EW were also detected for YW. Thus, the use of EC did not provide differences when added to CSM diets, but comparing CSM diet with ACMEC1, EW and YW could be recovered, which was not the case with EC2. This effect can be the response of EC1 with supplementation of xylanase, β-glucanase, and phytase and lower concentration of cellulase, pectinase, and protease (secondary role), which acted by increasing the use of non-starchy polysaccharides contained in the autoclaved castor meal, generating a similar result for EW and YW. According to Babalola *et al*. (2006), β-xylanase addition in broiler diets containing boiled castor seed meal improved apparent nitrogen and fiber absorption as well as feed transit time. However, EC2 did not improve EW or YW in ACM diet, because it contains only amylase, xylanase and protease, probably having reduced the intensity of action on the fibers present in the autoclaved castor meal or even some indirect detrimental effect on endogenous enzyme production.

According to Olukosi *et al*. (2007), various enzyme complexes are used in animal feed to increase the bioavailability of nutrients. Lima *et al*. (2011) evaluated the effect of phytase in CSM diets for laying quails and concluded that production performance and egg quality were improved. However, in the present experiment, because of the formulation strategy ("over the top"), the effects of EC1 containing phytase in CSM diet were not observed. Bayram *et al*. (2008) evaluated the effect of adding xylanase in CSM diets for laying quails and also observed no differences in egg production or quality. Pernollet (1978), in turn, stated that castor bean meal has crystalloid and globoid protein body ultra-structures that are absent in soybean meal. In the autoclaved castor meal, the phytin (containing phytate) is located in globoids when present in protein bodies. The differences between

the ability of EC to act on the substrate composed of autoclaved castor bean meal may be the reason for the more prominent action of EC1 in ACM diet, and this led to effects on EW and YW.

The use of EC1 in diets with 21% autoclaved castor meal, even if diets are formulated using the "over the top" criteria, may recover EW and YW to values equivalent to the production of quails receiving CSM diets. In this case, the recommendation of EC1 use rests on economic viability when eggs are sold by weight.

## CONCLUSIONS

The use of enzyme complex containing xylanase, β-glucanase, and phytase is recommended when 21% autoclaved castor meal is included in the diet of laying quails.

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