Turmeric and sorghum for egg-laying quails

Weslane Justina da Silva\textsuperscript{a}, Alison Batista Vieira Silva Gouveia\textsuperscript{a}, Fabricio Eumar de Sousa\textsuperscript{b}, Fabiana Ramos dos Santos\textsuperscript{a}, Cintia Silva Minafra-Rezende\textsuperscript{c}, Júlia Marixara Sousa Silva\textsuperscript{a} and Cibele Silva Minafra\textsuperscript{a}

\textsuperscript{a}Programa de Pós-Graduação em Zootecnia, Instituto Federal Goiano – Campus Rio Verde, IFGoiano, Rio Verde, Brasil; \textsuperscript{b}Departamento de Agronomia, Centro Universitário de Mineiros, UNIFIMES, Mineiros, Brasil; \textsuperscript{c}Centro de Pesquisa em Alimentos, Escola de Veterinária e Zootecnia, Universidade Federal de Goiás Campus II – Samambaia, Goiânia, Brasil

ABSTRACT

The aim of the present study was to assess the effect of adding different turmeric amounts to sorghum-based diets for Japanese quails on animal performance, animal metabolism, yolk colour, egg quality, blood and liver biochemical parameters and sensory attributes of the eggs. The study included 210 egg-laying quails aged 50 days and lasted for 90 days. The study had a completely randomised design with six treatments and five replicates with seven birds per replicate. A control corn-based feed and sorghum-based feeds to which different turmeric levels were added (0%, 0.5%, 1.0%, 1.5% and 2%) were tested. The results showed that the sorghum-based feeds with added turmeric levels did not affect animal performance, metabolisation of protein and ether extract, internal and external quality of eggs, serum biochemical profile, including calcium, phosphorous, protein and liver transaminase enzymes. Blood cholesterol and triglyceride levels decreased when 0.5% percentages of turmeric were added to the feed. Yolk colour of the treatments differed significantly from that of the control, but the yolks were considered well suited for consumption. Turmeric reduced the cholesterol and triglyceride levels in egg-laying quails.

ARTICLE HISTORY

Received 3 May 2017
Revised 13 July 2017
Accepted 24 July 2017

KEYWORDS

Cholesterol; quail farming; curcumin; egg; triglycerides

Introduction

Quail production has been increasing in recent years because of the potential for meat production, high egg production, commercial diversity and fast return on investment. Studies in the field of quail nutrition have focussed on specific topics, such as nutritional protein, energy and amino-acid requirements (Moraes et al. 2016). However, data on pigment agents and alternative foods and their effect on metabolism are still limited.

According to Moura et al. (2010), sorghum can replace corn in feeds for egg-laying Japanese quails; however, it lightens the colour of yolk and there is, therefore, an increasing interest in including pigment agents in feeds. However, carotenoid pigments, such as turmeric (\textit{Curcuma longa}) can be added to the feed of egg-laying quails to improve the colour of yolks.

\textit{Curcuma longa} popularly known as saffron has long been used for its strong flavour and striking yellowish colour. It is an Indian spice widely used in food and medicine. It is notable for presenting essential oils rich in volatile terpenes (such as turmerone, curneole and curcureenol) and pigments (such as curcumin, desmethoxycurcumin and bisdesmethoxicurcumin) (Ahsan et al. 1999; Sueth-Santiago et al. 2015). In the present study, it was found that the anti-inflammatory effect of the anti-inflammatory agent (Nonose et al. 2014), Immunostimulant (Varalakshmi et al. 2008; Srivastava et al. 2011), and the effects of the antimicrobial activity on the microorganisms.

These properties make curcumin a candidate for phytotherapeutic use and for functional nutrition, with a potential nutraceutical effect on animal nutrition (Putra et al. 2015; Günes et al. 2016; Marathe et al. 2016).

The functional and phytogenic properties of curcumin have effects on egg-laying quails and on the quality, integrity (Laganà et al. 2012; Saraswati et al. 2013; Saraswati and Tana 2016), external appearance, size, internal composition and nutritional potential of quail
eggs, which promote the growing consumption of quail eggs, as shown in several studies.

This study aimed to assess the effect of replacing corn with sorghum and including increasing turmeric levels (0%; 0.5%; 1.0%; 1.5% and 2.0%) on animal performance, yolk colour, egg quality, blood and liver biochemical profiles and sensory characteristics of the eggs.

**Material and methods**

The research project was approved by the animal research ethics committee of the Instituto Federal Goiano–Campus Rio Verde under protocol No. 002/2015. The study was conducted for approximately 90 days (three periods of 28 days of egg production plus an adaptation period of six days), between November 2015 and February 2016. Two hundred and ten female quails of the *Coturnix coturnix japonica* species, aged 50 days, were used. They were divided according to body weight of 170 g and distributed in galvanised wire cages that were 33 cm long, 25 cm wide and 20 cm high and had feeders and water dispensers with spouts, at a density of 117 cm²/bird. The study design was completely randomised with six treatments and five replicates with seven birds per replicate. The birds were housed with a 16-h lighting programme using 100 Watts fluorescent bulbs and natural light. Water and the experimental feeds were provided *ad libitum* twice a day, 8am and 4pm to reduce waste.

The experimental feeds were formulated according to the nutritional recommendations by Rostagno et al. (2011). They were isonitrative and isoenergetic to meet all the nutritional requirements of the egg-laying quails and consisted of rations based on corn and soybean meal, sorghum and soybean meal without turmeric powder and rations based on sorghum and soybean meal with inclusion of levels of 0%, 0.5%, 1%, 0.5%, 1.5% and 2.0% turmeric powder.

The turmeric powder was obtained in the region of the municipality of Iporá–Goiás. The turmeric rhizomes were collected, washed, dried, cut and air-dried. They were subsequently ground in a knife mill and sieved using a 1-mm mesh sieve. Turmeric was added to the feed to replace the inert material and the percentage compositions of the experimental feeds were adjusted, which allowed maintaining the same nutritional levels in all feeds. The turmeric chemical composition percentage has been analysed according to the methodology described by Silva and Queiroz (2002), of dry matter (DM), crude protein (CP), ether extract (EE), mineral matter (MM) and crude fibre (CF).

The mean temperatures and relative humidity of the environment were measured with a digital thermo-hygrometer during production cycles. The maximum temperature was 29.11 °C and the minimum temperature was 24.87 °C. The maximum humidity was 75.95% and the minimum humidity was 69.93%. The calculated composition and nutritional percentage levels of the feeds used during the experimental period are shown in Table 1.

The response variables for production performance were the following: feed intake (g) obtained by the difference between the amount of feed provided and the leftovers, feed conversion per mass of eggs produced during the 28-day cycle (kg/kg of eggs) from the division of the total feed consumed by the weight of the eggs produced, feed conversion per dozen of eggs (kg/dozen of eggs) calculated by multiplying the average feed intake by twelve, egg-laying percentage (%) and viability of eggs (%) obtained from the collection and counting of the number of intact, broken, cracked, thin bark, shelled and deformed eggs.

In order to verify the utilisation of the nutrients present in the diet, by quail, the digestibility of protein and fat was measured, since these are the main compounds of the egg, that is, its absorption is essential for the metabolism of egg production. In order to evaluate the digestibility, the excreta produced by birds between 50 and 55 days of age were collected twice a day during the experimental periods. The total collection period lasted ten days (five days of adaptation + five days of total excreta collection). The rations were weighed at the beginning and at the end of the total collection period in order to obtain the average feed intake. The traditional method of total collection of excreta was used, using ferric oxide (1%) as marker at the beginning and end of collection. The cages were lined with trays coated with plastics, properly identified, which were removed at each collection (12-hour interval) for excreta removal. The collected material was stored frozen until thawed. Subsequently, the excreta were thawed, homogenised, weighed and dried in a forced ventilation oven for 72 hours at 55 °C. Then, crude protein (CB) and ether extract (EE) were ground and analysed. Laboratory analyses of feed, food and excreta were performed according to the methodology described by Silva and Queiroz (2002), to estimate the metabolism coefficient of the nutrients present in the diet, i.e. what the bird ingested, which can actually be used in the organism supply and egg production.

For the quality of the eggs, a precision 0.01g and digital calliper was used, the internal egg quality was measured from the random selection of seven eggs, the weight of the whole egg (g) measured on a precision scale of 0.01 g and the number of eggs per plot,
the average egg weight of the plots shall be calculated, egg mass (g) is calculated by dividing egg production by the mean weight (g), obtained by the separation of the yolk and weight given by scales, weight of albumen (g) given by the difference between the weight of the egg and the weights of the bark and the yolk, percentage of yolk (%) obtained considering the total weight of the egg and the weight of the yolk.

Yolk height (mm) measured in the central portion of the same with a digital calliper, yolk pH was measured with digital pH, yolk diameter (mm) measured by a digital calliper and yolk index given by the formula: height ratio (g), obtained by the difference between the weight of the egg and of the weights of the bark and the yolk, percentage of albumen (%) was determined by difference: 100 – (percentage of yolk% (mm), measured at the nearest portion of the yolk with a pachymeter, pH of albumen was measured with digital pH, albumin diameter (mm) measured by a digital calliper, albumen index (g/cm³) obtained by immersing the eggs in saline solution and measuring by oil densimeter and Haugh unit obtained by the formula:

\[ UH = 100 \times \log (H - 1.7 \times P0, 37 + 7.6). \]

The external quality of the eggs was obtained from eggshell weight (g), the shells were dried in a forced ventilation oven for 24 h at 105 °C and weighed in a precision scale of 0.01 g, percentage of bark (%) by weight of the shell multiplied by 100 divided by the total weight of the egg and shell thickness (mm) including the membranes was obtained by the mean value three different points at the two poles and in the lateral region of the egg, with digital calliper, with accuracy of 0.01 mm.

Yolk colour was evaluated using a calibrated colorimeter according to Bible and Singha (1993) immediately after egg collection. The eggs were washed under running water and dried with paper towel. They were then opened with scissors to remove the yolks, which were placed in a disposable cup and subsequently in the flask that was placed in the colourimeter to measure the L\(^*\), a\(^*\) and b\(^*\) variables. The readings were recorded in spreadsheets for statistical analysis.

Plasma samples were collected from two quails per replicate of each treatment by heart puncture to determine the birds’ metabolism on the basis of blood biochemical variables. The labelled tubes were centrifuged at 6000 rpm for 10 min to obtain the serum used for the analysis of calcium (Ca, mg/dL), phosphorus (P, mmol/L), triglycerides (T, mg/dL) and cholesterol (Col, mg/dL). Calcium was determined colorimetrically through a cresolphthalein complex in

Table 1. Calculated composition and nutritional percentage levels of the corn-based diet and sorghum-based diet with and without added turmeric levels.

| Ingredients, g/kg | Sorghum | 560.0 | 560.0 | 560.0 | 560.0 | 560.0 | – |
|------------------|----------|-------|-------|-------|-------|-------|---|
| Corn 7.88 %      | –        | –     | –     | –     | –     | –     | 560 |
| Soybean meal 45% (Crude protein) | 269 | 269 | 269 | 269 | 269 | 287 |
| Soybean oil      | 40.9     | 40.9  | 40.9  | 40.9  | 40.9  | 25.1  |
| Calcium carbonate| 81       | 81    | 81    | 81    | 81    | 82    |
| Monodicalcium phosphate | 11.1 | 11.1  | 11.1  | 11.1  | 11.1  | 12.2  |
| Curcuma longa    | –        | 5     | 10    | 15    | 20    | –     |
| Mineral premix*  | 1        | 1     | 1     | 1     | 1     | 1     |
| Vitamin premix*  | 2        | 2     | 2     | 2     | 2     | 2     |
| Salt             | 4        | 4     | 4     | 4     | 4     | 3.8   |
| L-Lysine         | 4.8      | 4.8   | 4.8   | 4.8   | 4.8   | 3.9   |
| DL-Methionine    | 4        | 4     | 4     | 4     | 4     | 4     |
| Inert            | 20       | 15    | 10    | 5     | –     | 17    |
| L-Threonine      | 1.2      | 1.2   | 1.2   | 1.2   | 1.2   | 1     |
| BHT              | 1        | 1     | 1     | 1     | 1     | 1     |
| Total            | 1000.00  | 1000.00 | 1000.00 | 1000.00 | 1000.00 | 1000.00 |

Calculated levels

| Metabolisable energy, Kcal/kg | 2800 | 2800 | 2800 | 2800 | 2800 |
| Crude protein, %              | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| Crude fibre, %                | 4.38  | 4.38  | 4.38  | 4.38  | 4.38  |
| Total lysine, %               | 1.23  | 1.23  | 1.23  | 1.23  | 1.23  |
| Total methionine, %           | 0.64  | 0.64  | 0.64  | 0.64  | 0.64  |
| Total threonine, %            | 0.77  | 0.77  | 0.77  | 0.77  | 0.77  |
| Total tryptophan, %           | 0.25  | 0.25  | 0.25  | 0.25  | 0.25  |
| Calcium, %                    | 3.24  | 3.24  | 3.24  | 3.24  | 3.24  |
| Phosphorous, %                | 0.33  | 0.33  | 0.33  | 0.33  | 0.33  |
| Sodium (HCl), %               | 0.17  | 0.17  | 0.17  | 0.17  | 0.17  |

*Includes the levels of 0.5%, 1%; 1.5%, and 2% of turmeric replacing the inert material. BHT antioxidant. Vitamin A 176,550.00 UI/Kg, Vitamin B1 26 mg, Vitamin B12 5 000 mcg, Vitamin B2 57.00 mg, Vitamin B6 32.00 mg, Vitamin D3 42,560 UI/Kg, Vitamin E 131,000 UI/Kg, Vitamin K3 30.00 mg, Biotin 38 mg, Choline 3.250 g, Niacin 380.00 mg, Folic acid 250 mg, Pantothenic acid 150.00 mg, Cobalt 75 mg, Copper 1500 mg, Iron 15 g, Iodine 250 mg, Manganese 20 g, Selenium 16.700 mg, Zinc 15.0 g.
alkaline medium. The phosphorus reacted with the molybdate in the acid medium, forming the complexo-
phosphomolybdate. The addition of an alkaline solu-
tion allows this complex to be reduced by ascorbic
acid, giving rise to a new blue phosphomolybdate
complex. In parallel, the precipitated prior proteins
dissolve. Triglycerides undergo enzymatic reactions
producing products formed by the oxidation of
4-aminoantipyrine (4-antipyrilquinonimine) is reddish
in colour and its intensity is directly proportional to
the concentration of triglycerides in the serum. The
red colour, formed by the reaction, is measured in
spectrophotometer or photocolorimeter with max-
imum absorption at 510 nm or green filter. Cholesterol
undergoes enzymatic reactions generating products
formed by the oxidation of 4-aminoantipyrine (4-anti-
pyrilquinonimine) is reddish in colour and its intensity
directly proportional to the concentration of choles-
terol in the serum.

After killing, the liver was removed from the birds
which was frozen in liquid nitrogen, then homoge-
nised (1g of tissue and 9 ml of water) and then centri-
fuged at 8000 rpm at 40 °C for 10 min. The
supernatant was collected for the determination, in
triplicate, of the total protein (g/dL), measured by the
biuret reagent, a solution of copper sulphate, triso-
dium citrate, sodium carbonate and sodium hydroxide
which reacted with the proteins of the sample, form-
ing a complex (GOT, IU/L), and glutamate-pyruvate
(glutamate), which are proportional to the protein con-
centration of the sample, and the enzymatic activity
of the transaminase enzymes. Transaminase (GPT, IU/L),
identify liver function, from the quantified levels it is
possible to verify whether or not functional damage to
the liver occurred, the analyses were performed using
commercial DOLES kits, according to methodology of
Minafra et al. (2010). In the transaminase the pyruvate
and the oxalacetate formed are proportional to the
enzymatic activity and measured through the forma-
tion of its intensely stained hydrazones in alkaline
medium.

The sensory analysis of the eggs in the present study
was approved by the Research Ethics Committee of the
Instituto Federal de Educação, Ciência e Tecnologia
Goiano, according to Resolution CNS 466/12 under No.
CAAE 58595316.2.0000.0036. It was performed using
the preference test described by Minim (2012). The
hedonic scale evaluation form was used for the sensory
attributes, namely, colour, aroma and flavour of the
quail eggs. The analysis was performed in the Sensory
Analysis Laboratory of the IF Goiano–Campus Rio Verde.
Fifty sensory assessors aged more than 18 years were
consulted. The analysis was performed according to
good production practices. Microbiological analyses
were performed to identify and quantify Staphylococcus
aureus, to determine total coliforms and thermophilic
bacteria using the most probable number (MPN)
method and Salmonella sp., according to the method
described by the Normative Instruction No 62 (BRASIL
2003) for cooked eggs. The results were negative, thus
confirming that the eggs did not pose any risk to the
consumers and ensuring food safety, and only then
were samples given to the assessors for evaluation.

The results obtained were subjected to variance
analysis using the general linear model procedure with
the SAEG (2007) software and the means were com-
pared by the Dunnett test (5%). Regression analysis
with the level of significance set at 5% was used when
the F-test was significant.

Results
Turmeric had a chemical composition percentage of
88.85% dry matter (DM), 15.82% crude protein (CP),
3.72% ether extract (EE), 1.073% mineral matter (MM)
and 7.79% crude fibre (CF).

The performance of quails was not affected by the
turmeric levels ($p > .05$). In addition, it did not differ
between the quails on the sorghum-based diet and
those on the corn-based diet, which showed that the
quails’ performance was within the expected values
(Table 2).

Table 3 shows the coefficient of metabolisation of
crude protein and ether extract in Japanese quails fed
with sorghum-based diets with different levels of
added turmeric.

| Table 2. Performance in the production phase of Japanese quails fed with sorghum based rations with inclusion of turmeric. |

| Turmeric levels, % | Control | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | $p$ Value | SEM |
|-------------------|---------|-----|-----|-----|-----|-----|-----------|-----|
| FI, g             | 28.23   | 28.49| 29.32| 29.50| 30.20| 25.02| .089      | 0.106|
| FCM, Kg Kg$^{-1}$ | 2.40    | 2.27| 2.39| 2.37| 2.36| 1.94| .214      | 0.111|
| FCDz, g           | 338.70  | 341.93| 351.80| 353.94| 362.40| 300.29| .081      | 0.0961|
| LP, %             | 88.00   | 82.71| 80.14| 89.28| 89.14| 82.42| .0127     | 0.0772|
| Viability, %      | 99.07   | 99.65| 99.11| 98.13| 98.86| 99.30| .0309     | 0.0776|

FI: feed intake per day in grams; FCM: egg mass feed conversion; FCDz: food per dozen eggs; LP: percentage of posture and percentage of viable eggs; SEM: standard error of the mean.
As shown in Table 3, there were no differences ($p > .05$) in the coefficients of metabolisation of dry matter, crude protein and ether extract between the diets.

The quality of the eggs tested in this study did not differ between the diets (Table 4).

With regard to the $L^a$, $a^b$ and $b^c$ parameters of yolk colour of quail eggs (Table 4), the corn-based treatment conferred the greatest pigmentation to the yolk, sorghum caused depigmentation and the addition of turmeric led to increased pigmentation but not as much as the control corn treatment.

Blood and liver laboratory analyses are an important tool for health monitoring and disease diagnosis and treatment. In addition, there is a great concern regarding animal welfare and it is thus necessary to obtain reference biochemical values to better assess the quails’ physiological status.

As shown in Table 5, there were no significant differences ($p > .05$) in the levels of Ca and P and in the Ca/P ratio. However, cholesterol and triglycerides levels were significantly different, both by the Dunnett test and between the turmeric levels ($p < .05$). In the Dunnett test, corn-based feeds and sorghum-based feeds without turmeric differed from sorghum-based feeds with added turmeric; cholesterol and triglyceride levels in quails decreased with increasing turmeric levels.

The concentrations of serum calcium obtained in this study were normal. Calcium in birds is higher than those in mammals (30 g/L) and depends on the reproduction stage of females and on the amount of

### Table 3. Coefficients of digestibility of crude protein (CDCP) and ether extract (CDEE) in Japanese quails fed with sorghum-based diets with different levels of added turmeric.

| Turmeric levels, % | CDCP | CDEE |
|-------------------|------|------|
| Control 0.0 | 84.687 | 23.828 |
| 0.5 | 86.765 | 26.141 |
| 1.0 | 79.301 | 23.517 |
| 1.5 | 85.068 | 24.287 |
| 2.0 | 84.744 | 22.486 |
| $p$ Value | .107 | .171 |
| SEM | 0.051 | 0.067 |

**SEM:** standard error of the mean.

### Table 4. Quality of laying quails eggs fed with rations containing turmeric levels, egg weight, egg unit mass, specific weight and Haugh Unit; Yolk: weight, percentage, height, pH, diameter, index; Colour of the gem: parameters $L^a$, $a^b$, and $b^c$; Weight, percentage, height, pH, diameter, albumen index; Peel: weight, percentage and thickness.

| Turmeric levels, % | Egg Whole | Yolk |
|-------------------|-----------|------|
| Weight, g | 11.713 | 12.031 |
| Mass, g | 9.474 | 9.057 |
| Specific weight, g/cm$^3$ | 1.072 | 1.076 |
| Haugh unit | 85.196 | 85.282 |
| $p$ Value | .107 | .097 |
| SEM | 0.063 | 0.093 |

### References

372 W. J. D. SILVA ET AL.
There were no significant differences (p > .05) in protein and transaminase levels in the liver tissue of egg-laying quails. The results showed that there was no effect of the tested feeds on the production of liver enzymes. The analysed transaminases are of mitochondrial origin and contribute to the diagnosis of pathological changes such as liver necrosis.

The results of the sensory analysis of colour, aroma and flavour of quail eggs are shown in Table 6. The comparison between eggs produced with diets based on corn and sorghum showed that there was no significant effect of the sorghum-based treatments with and without turmeric (at any level) (p > .05) on the colour of egg yolks. The sensory assessors were indifferent to this parameter, neither liking nor disliking it; however, they preferred the colour of the egg yolks of the control quails. There was a difference in the results of sensory colour analysis by the Dunnett test.

According to the aroma scores, the eggs of quails fed with the control feed and those of quails fed sorghum with 0.5%, 1.0% and 2% of turmeric were well accepted, i.e. their aroma was slightly liked by the assessors. However, the assessors slightly disliked the aroma of the eggs from the sorghum-based treatments with 0% and 1.5% of turmeric.

The flavour scores of eggs from the treatments with 0% and 0.5% turmeric (with the assessors slightly liking the flavour) were lower than the scores of the other treatments.

With regard to the preference order of the egg samples assessed in this study, considering all eggs tested, the best score was given to eggs from quails fed with the corn-based control feed (55.17%), because of the greater yolk pigmentation.

Eggs from sorghum treatments with and without inclusion of turmeric, it was observed that the highest preference was for eggs of birds fed sorghum-based rations with inclusion of 1% turmeric which scored 27.6% as compared to the others within the preferred second position as compared to the total of the eggs tasted.

Overall, considering all the eggs, the third place in the preference order was attributed to eggs from the sorghum-based feed with 0.5% turmeric (37.93%). The fourth, fifth and sixth positions were occupied by eggs laid by quails fed with sorghum-based feed with 2%, 1.5% and 0% turmeric, respectively. The respective scores were 24.145%, 20.7% and 41.38%.

Faced with the sensory variables under assessment and the order of preference of eggs, 93.1% of the sensory assessors approved the product and said that
they would be interested in buying the eggs under this study.

Discussion

Feed intake by quails was not affected by the inclusion of turmeric (Table 2); however, Kilany and Mahmoud (2014) evaluated Japanese quail diets with added turmeric powder with and without enzymes and observed a decrease in the intake of feeds with turmeric and an even lower intake when the enzyme was added, with an improvement in feed efficiency.

As shown in Table 3, the crude protein was efficiently digested by the quails; however, no data on nutrient metabolism in quails fed with turmeric were found in the literature.

Different from what occurred in this study, Saraswati et al. (2013) analysed the supplementation of quail feed with turmeric powder (0, 13.5, 27 and 54 mg/quail/day) and observed an improvement in the internal and external quality of the eggs; the values of the response variables increased with increasing turmeric levels in the feed.

With regard to quail yolk colour, the use of turmeric levels of up to 2% was not sufficient to increase yolk pigmentation (Table 4). Laganà et al. (2012) obtained the same result when they included 2% of turmeric powder in the feed of Hy-Line Brown egg-laying chickens, i.e. yolk pigmentation was insufficient for the commercialisation of the eggs.

Rojas et al. (2015) added a natural pigment agent (urucum meal) and synthetic pigment agents (canthaxanthin and apocarotenal) to feeds and observed a significant increase in the intensity of yolk colour in egg-laying hens caused by a greater deposition of pigments, lipids and proteins.

According to what is observed in Table 5, we therefore, presume in this study that there was poor metabolism of the turmeric pigment by quails, because dietary turmeric is partially absorbed together with the micelles in the intestine and transported to the liver by low-density lipoproteins (VLDL-c). The latter exist in a lower quantity than high-density lipoproteins (HDL-c). HDL-c carries less polar molecules, such as xanthophylls, because carotenoids have different polarities. Therefore, the proportion of carrier lipoproteins determines the concentration of turmeric in the liver. Approximately 20% of the turmeric ingested by the animal is not absorbed. When it reaches the caecum and the colon, it is metabolised by E. coli through the action of NADPH-dependent dihydrocurcumin reductase, a molecule that catalyses the oxidation via reduction reactions. Lipids, (fat-soluble) pigments and proteins are synthesised in the liver and transported by plasma lipoproteins to be deposited in developing oocytes and are precursors for the formation of other compounds (phosvitin, lipovitellin and vitellogenin) through lipolysis. These compounds can form complexes with yolk phospholipids and cholesterol (Hassaninasab et al. 2011; Lima et al. 2012).

Diet can affect the levels of cholesterol and triglycerides because these compounds are directly related to the type of ingested foods and their storage capacity or mobilisation of fatty tissues and synthesis in the liver. Plasma cholesterol in birds increases considerably as a result of vitellogenesis and egg formation, its values ranging between 100 and 250 mg/L (Thrall et al. 2004).

The finding (Table 5) that there was a decrease in serum cholesterol and triglyceride levels in quails fed with turmeric was also observed in the study by Saraswati et al. (2013), in which the cholesterol level decreased from 177.4 mg/dl to 97 mg/dl with increasing turmeric levels.

Cholesterol levels observed in this study were similar to those presented by Fanchiotti et al. (2010). These authors also reported that lipid metabolism in egg-laying hens is faster because they require a greater mobilisation of fatty acids. According to literature, cholesterol blood levels in quails were within the normal range, i.e. between 130 mg/dL and 270 mg/dL.

The present study clearly showed a decrease in the levels of cholesterol with the addition of turmeric to the diets. Quails have been used for experimentation and pharmacological tests for the treatment and dietary control of cholesterol levels (Botelho et al. 2014; Adeniyi et al. 2016). Cholesterol synthesis in animals occurs as a result of the storage of energy in the form of fat. High synthesis of acetyl-CoA induces an increase in insulin production. Insulin is then released into the bloodstream leading to the increase in the levels of enzymes metabolising low-density lipoprotein cholesterol, which are lipoproteins that are involved in the transportation, catalysis and storage of triglycerides in adipose tissue (Liu et al. 2015).

During vitellogenesis (yolk formation) in egg-laying poultry, oestrogen promotes an increase in the levels of liver triglycerides and cholesterol that are released into the blood plasma and transported by LDL and VLDL and stored in the yolk. Carbohydrate intake by poultry causes an increase in triglyceride levels, which in turn promotes lipogenesis in adipose tissue. Lipogenesis occurs via the action of lipases that catalyse and hydrolyse plasma triglycerides, fatty acids and glycerol. The latter enter adipocytes and are...
re-esterified and stored as triglycerides (Jacobsen et al. 2013; Costa et al. 2017).

Turmeric has the ability to de inhibit triglyceride synthesis in liver cells. Its inhibitory action varies according to its concentration; doses of >0.05 g/100 g have already been shown to result in the reduction of liposynthesis. The expression of genes involved in energy metabolism is affected by turmeric, with a reduction in the accumulation of fat in blood and tissues and a decrease in intracellular levels of lipids (Alappat and Awad 2010; Budiman et al. 2015).

With regard to the effect of the addition of turmeric to diets on triglyceride levels, Saraswati et al. (2013) observed that the inclusion of turmeric in feeds resulted in the decrease of serum triglyceride levels, which reached 86.63 mg/dl, and a decline in serum cholesterol in quails.

In an investigation on the biochemical response of Japanese quails to diets with added turmeric (54 mg/quail/day and 108 mg/quail/day), Putra et al. (2015) observed a reduction in the values of triglycerides with increasing percentages of turmeric.

In this study the levels of GOT and GPT (Table 5) were higher than those obtained by Kilany and Mahmoud (2014) when they investigated the effects of turmeric added to diets for Japanese quails. Saraswati and Tana (2016) obtained similar results, i.e. a decrease in GOT when 54 mg/bird/day and 108 mg/bird/day of turmeric were added to feeds.

Al-Daraji et al. (2010) reported GOT and GPT values in Japanese quails of 240.2 U/L and 12.12 U/L, respectively, which were in line with the results of Scholtz et al. (2009), who obtained GOT and GPT ranges of 243–562 U/L and 4.5–8.5 U/L, respectively.

In the present study there was no damage to liver metabolism of quails fed with sorghum and turmeric. There are anecdotal reports that turmeric protects the liver against toxic liver damage and promotes bile flow.

Conclusions

Different turmeric levels in sorghum-based feeds of egg-laying quails did not affect animal performance, quality of eggs and liver enzyme levels. Yolk pigmentation did not differ in comparison with corn-based feeds. All levels of added turmeric caused a decrease in blood cholesterol and triglycerides. The assessors manifested their interest in buying these eggs.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Adeniyi PO, Obatolu VA, Farinde EO. 2016. Comparative evaluation of cholesterol content and storage quality of chicken and quail eggs. World J Nutr Health. 4:5–9.

Ahsan H, Parveen N, Khan NU, Hadi SM. 1999. Pro-oxidant, anti-oxidant and cleavage activities on DNA of curcumin and its derivatives demethoxycurcumin and bisdemethoxycurcumin. Chem Biol Interact. 21:161–175.

Alappat L, Awad A. 2010. Curcumin and obesity: evidence and mechanisms. Nutr Rev. 68:729–738.

Al-daraji HJ, Al-mashadani HÂ, Al-hayani WK. 2010. Effect of feeding diets containing sesame oil or seeds on productive and reproductive performance of laying quail. Al-Anbar J Vet Sci. 3:56–67.

Bible BB, Singha S. 1993. Canopy position influences cIELab coordinates of peach color. Hortsience, Alexandria. 28:992–993.

Botelho GG, Falbo MK, Ost PR, Czekoski ZM, Giotto FM, Goldoni EC, Morais RN. 2014. Physiological performance of quails that underwent dietary and pharmacological manipulation of cholesterol. J Anim Physiol Anim Nutr. 99:424–429.

BRASIL. 2003. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa 062, de 26 de agosto de 2003. Métodos Analíticos Oficiais para Análises Microbiológicas para Controle de Produtos de Origem Animal e Água. Diário Oficial da União, Brasília, 18 set.

Budiman I, Tjokropranoto R, Widowati W, Fauziah N, Erawijantari PP. 2015. Potency of turmeric (Curcuma longa L) extract and curcumin as anti-obesity by inhibiting the cholesterol and triglycerides synthesis in HepG2 cells. Int J Res Med Sci. 3:1165–1171.

Capitelli R, Crosta L. 2013. Overview of psittacine blood analysis and comparative retrospective study of clinical diagnosis, hematology and blood chemistry in selected psittacine species. Vet Clin North Am Exot Anim Pract. 16:71–120.

Costa FAD, Tavernari FC, Costa OAD, Castro FF, Remus A. 2017. Enriquecimento com ácidos graxos da série ômega 3 em carne de aves e ovos. PUBVET. 11:113–123.

Fanchiotti FE, Moraes GHK, Barbosa AA, Albinio LFT, Cecon PR, Moura AMA. 2010. Avaliação de óleos, carvão vegetal e vitamina E no desempenho e na concentrações lipídicas do sangue e dos ovos de poedeiras. Rev Bras Zootec. 39:2676–2682.

Gunes H, Gulen D, Mutlu R, Gumus A, Tas T, Topkaya AE. 2016. Antibacterial effects of curcumin: An in vitro minimum inhibitory concentration study. Toxicol Ind Health. 32:246–250.

Hassaninasab A, Hashimoto Y, Tomita-yokotani K, Kobayashi M. 2011. Discovery of the curcumin metabolic pathway involving a unique enzyme in a intestinal microorganism. PNAS. 108:6615–6620.

Jacobsen C, Nielsen NS, Horn AF, Sørensen ADM. 2013. Food enrichment with omega-3 fatty acids. Cambridge: Elsevier.

Kilany OE, Mahmoud MMA. 2014. Turmeric and exogenous enzyme supplementation improve growth performance and immune status of Japanese quail. World Vet J. 4:20–29.

Laganá C, Cachoni PC, Nogueira TPH, Moraes JE, Politi BSÊS. 2012. Influence of the natural dyes bixin and curcumin in...
the shelf life of eggs from laying hens in the second production cycle. Anim Sci. 34:155–159.

Lima JP, Lopes CO, Dias NAA, Pereira MCA. 2012. Atividade e Biodisponibilidade dos Carotenoides no Organismo. Revista Ciências Em Saúde. v. 2, n.1.

Liu Q, Wang YT, Lin L. 2015. New insights in the antiobese activity from Garcina mangostana. Food Funct. 30: 383–393.

Marathe SA, Balakrishnan A, Negi VD, Sakorey D, Chandra N, Chakravortty D. 2016. Curcumin reduces the motility of Salmonella enterica Serovar Typhimurium by binding to the flagella, thereby leading to flagellar fragility and shedding. J Bacteriol. 198:1798–1811.

Minafra CS, Marques SFF, Stringhini JH, Ulhoa CJ, Rezende CSM, Santos JS, Moraes GHK. 2010. Perfil bioquímico do soro de frangos de corte alimentados com dieta suplementada com alfa-amilase de Cryptococcus flavus e Aspergillus niger HM2003. Rev Bras Zootec. 39:2691–2696.

Minim VPR. 2012. Análise sensorial: estudos com consumidores. 2a edição, 1a reimpressão, editora.Viçosa (MG): UFV- Universidade Federal de Viçosa; 225p.

Moraes CA, Fernandes EA, Silveira MM, Martins JMS, Litz FH, Saar AGL, Carvalho CMC. 2016. Performance and meat chemical composition of quails fed with different sorghum levels instead of corn. Ciência Rural. 46:933–936.

Moura AMA, Fonseca JB, Rabello CB, Takata FN, Oliveira NTS. 2010. Desempenho e qualidade do ovo de codornas nipônias alimentadas com ração contendo sorgo. Rev Bras Zootec. 39:2697–2702.

Nonose N, Pereira JA, Machado PRM, Rodrigues PR, Sato DT, Martinez CAR. 2014. Oral administration of curcumin (Curcuma longa) can attenuate the neutrophil inflammatory response in zymosan-induced arthritis in rats. Acta Cir Bras. 29:727–734.

Putra SHJ, Saraswati TR, Isdadiyanto S. 2015. Profile triglycerides Japanese quail (Coturnix coturnix japonica) after giving turmeric (Curcuma longa) powder. Internat J Sci Eng. 8:65–68.

Rojas VV, Callacna MC, Arnaiz VP. 2015. Use of an additive canthaxanthin based and annatto extract in diets of laying hens and its effect on the color of the yolk and the egg shelf life. Scientia Agropecuaria. 6:191–199.

Rostagno HS, Albino LFT, Donzele JL, Gomes PC, Oliveira RF, Lopes DC, Ferreia AS, Barreto LST, Euclides RF. 2011. Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais de aves e suínos. 3a edição, Viçosa, MG: UFV; 252 p.

SAEG. 2007. Sistema para Análises Estatísticas, Versão 9.5: Fundação Arthur Bernardes - UFV - Viçosa.

Saraswati TR, Tana S. 2016. Physiological condition of first female and male offspring of Japanese quail (Coturnix japonica) whose parents were supplemented by turmeric powder. J World Poult Res. 6:59–65.

Saraswati TR, Manalu W, Ekastuti DR, Kusumorini N. 2013. The role of turmeric powder in lipid metabolism and its effect on quality of the first quails egg. J Indones Trop Animal Agriculture. 38:123–130.

Scholtz N, Halle I, Flachowsy G, Sauerwein H. 2009. Serum chemistry reference values in adult Japanese quail (Coturnix coturnix japonica) including sex-related differences. Poult Sci. 88:1186–1190.

Silva DJ, Queiroz AC. 2002. Análises de alimentos (métodos químicos e biológicos). 3.ed. Viçosa (MG): Editora UFV.