RBSPA

Rev. Bras. Saúde Prod. Anim., Salvador, v.23, 01 - 09, e202000162022, 2022
http://dx.doi.org/10.1590/S1519-994002000162022

Animal Production and Environment
Received on: 07/04/2020
Accepted on: 08/02/2021

# Foeniculum vulgare (fennel) and Cymbopogon winterianus (citronella) essential oils to replace a growth promoter in the diet of European quails

*Óleos essenciais de Foeniculum vulgare (erva doce) e Cymbopogon winterianus (citronela) em substituição a um promotor de crescimento na dieta de codornas europeias*

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## ABSTRACT

The objective of this study was to evaluate the replacement of a growth-promoting antibiotic by fennel (*Foeniculum vulgare*) and citronella (*Cymbopogon winterianus*) essential oils in the quail diet on performance variables (weight gain, feed intake, feed conversion), as well as the carcass and cut yield. To do so, 240 one-day-old male and female European quails were distributed in a completely randomized design with four treatments, five replications and 12 animals per experimental unit. The treatments consisted of: PC – positive control diet without fennel or citronella essential oils and with the growth promoter (zinc bacitracin); NC – negative control diet without essential oils and without growth promoter; CEO - Diet with +0.078% citronella essential oil without the growth promoter; and FEO - Diet with +0.078% fennel essential oil without the growth promoter. The experiment lasted 42 days, in which the performance variables were analyzed in three periods (1-14 days; 14-21 days; and 22-42 days) and the carcass and cut yield in two periods (at 21 and 42 days). The observed data were submitted to analysis of variance and the comparison of means was performed using the Tukey's test at 5% significance. The presence of essential oils positively influenced ($P<0.05$) the performance variables and the carcass and cuts yield in all analyzed periods. The use of fennel and citronella essential oils to replace zinc bacitracin in the diet of European quails improves performance and the carcass and cut yield.
**Keywords**: phytogenic additives, carcass, coturniculture, performance.

ISSN 1519 9940

## RESUMO

Objetivou-se avaliar a substituição de um antibiótico promotor de crescimento por óleos essenciais de erva-doce (*Foeniculum vulgare*) e citronela *(Cymbopogon winterianus)* na dieta de codornas sobre o desempenho, rendimento de carcaça e cortes. Para isso, foram utilizadas 240 codornas europeias machos e fêmeas de um dia de idade distribuídos em delineamento inteiramente ao acaso com quatro tratamentos, cinco repetições e 12 animais por unidade experimental. Os tratamentos consistiram em: CP- Dieta sem os óleos essenciais de erva-doce ou citronela e com o promotor de crescimento (bacitracina de zinco); CN- Dieta sem os óleos essenciais e sem o promotor de crescimento; OC- Dieta com + 0,078% de óleo essencial de citronela sem o promotor de crescimento; OED- Dieta com + 0,078% de óleo essencial de erva-doce sem o promotor de crescimento. O experimento teve duração de 42 dias, no qual as variáveis de desempenho foram analisadas em três períodos (1-14 dias; 14-21 dias e 22-42 dias) e o rendimento de carcaça e cortes em dois períodos (aos 21 e 42 dias). Os dados observados foram submetidos à análise de variância e a comparação das médias foi realizada pelo teste de Tukey a 5%. A presença dos óleos essenciais influenciou positivamente ($P<0,05$) as variáveis de desempenho e o rendimento de carcaça e cortes em todos os períodos analisados. A utilização de óleos essenciais de erva-doce e citronela em substituição a bacitracina de zinco na dieta de codornas europeias melhora o desempenho e o rendimento de carcaça e cortes.

**Palavras-chave:** aditivos fitogênicos, carcaça, coturnicultura, desempenho.

## INTRODUCTION

The success of the poultry sector and the development of new nutritional tools have made it possible to optimize animal production, reduce environmental impacts and improve the quality of products that reach the consumer. In this context, additives are intended to beneficially modify the physicochemical, sensory and microbiological characteristics of the feed rations, even though they are not nutritious substances (Lemos et al. 2016).

Many additives, including growth promoters, are periodically used to control the proliferation of pathogens in the intestinal segment of birds. However, the use of antimicrobials in animal feed has been restricted in several countries in recent years because they present the possibility of selecting resistant microorganisms and antibiotic resistance by pathogenic bacteria to humans, becoming an obstacle to commercialize meat in domestic and foreign trade (Reis et al. 2014).

Thus, research has been intensified for alternatives which may replace antimicrobial additives in order to eliminate the risks, especially to human health. One of the alternatives presented by the scientific community has been the use of phytogenic additives, with essential oils standing out among them. Phenolic compounds, saponins and other secondary compounds present in fennel and citronella have a positive effect on the production and health of animals due to their ability to inhibit the growth of undesirable microorganisms in the

intestine and improve the digestibility of nutrients, in turn favoring performance and better carcass yield (Al-snafi, 2018; Verma et al. 2020; Lee et al. 2012).

Plant essential oils have been shown to be effective when added to replace antimicrobials in the diets of broilers (Nogueira et al. 2017); however, there are few studies with broiler quails, a segment of poultry farming which has shown economic potential for needing small production space, low feed intake/consumption by animals, combined with little initial investment for production.

Therefore, the objective herein was to evaluate the effectiveness of replacing an antimicrobial (zinc bacitracin) by fennel (*Foeniculum vulgare*) and citronella (*Cymbopogon winterianus*) essential oils in the diets of European quails on productive performance, carcass and cut yield.

## MATERIAL AND METHODS

The experiment was conducted in the poultry sector of the Rural Health and Technology Center of the Federal University of Campina Grande, Patos Campus, Paraíba, Brazil, and approved by the Ethics Committee on the Use of Animals (CEUA/UFCG) under protocol no.09/2012.

A total of 240 one-day-old female and male European quails (*Coturnix coturnix coturnix*) were used to perform the experiment. The quails were housed in galvanized wire cages equipped with nipple drinkers and trough feeders. In addition, 100W lamps were used during the initial 14 days of the experimental period to provide warmth to the quails. The quails were distributed in a completely randomized design consisting of four treatments, five replications and 12 quails per experimental unit. The treatments consisted of: PC – Positive control diet without fennel or citronella essential oils and with the growth promoter (zinc bacitracin); NC – negative control diet without essential oils and without growth promoter; CEO - Diet with + 0.078% citronella essential oil without the growth promoter; FEO - Diet with +0.078% fennel essential oil without the growth promoter. Moreover, 15g of zinc bacitracin was used for every 1000 kg of feed in the positive control diet. The usage level of both essential oils was determined from the analysis of minimum inhibitory concentration according to the methodology described by Silveira et al. (2012).

Fennel and citronella essential oils have high volatility due to their chemical composition, and therefore an adaptation in their management was necessary to introduce them into the feed in an attempt to reduce losses due to volatility. The essential oils mixed into the diet occurred in a single dose daily in the morning, being mixed in the diet without soybean oil in a portion of 25% of the total daily intake of the birds, taking into account the daily intake of the experimental unit of the previous day, then diluted in soybean oil according to the methodology described by Teixeira et al. (2013). After observing the feed ration intake containing the essential oils, the ration was offered ad libitum.

The experimental diets (Table 1) were formulated based on corn and soybean meal, calculated according to the recommendations of Silva & Costa (2009). The essential oils of both plants were obtained at the Plant Health Laboratory of the Center for Human, Social and Agrarian Sciences, Federal

University of Paraíba, Campus III, in Bananeiras, PB, Brazil.

**Table 1**. Composition and nutritional values of the reference diet (negative control) for meat quails in the initial and final stages of rearing.

| Ingredients (kg) | 1 to 21 days | 22 to 42 days |
|---|---|---|
| Ground corn | 51.634 | 58.273 |
| Soybean meal (45%) | 43.609 | 36.949 |
| Soy oil | 1.135 | 2.307 |
| Limestone | 1.126 | 0.935 |
| Dicalcium phosphate | 1.058 | 0.828 |
| Common salt | 0.314 | 0.270 |
| L-Lysine HCL | 0.279 | 0.000 |
| DL-Methionine | 0.419 | 0.217 |
| L-Threonine | 0.276 | 0.071 |
| Mineral Supplement[1] | 0.100 | 0.100 |
| Vitamin Supplement[2] | 0.050 | 0.050 |
| Total | 100.00 | 100.00 |
| Calculated nutritional value (%) | | |
| Metabolizable energy (Kcal/kg) | 2.900 | 3.050 |
| Crude protein | 25.00 | 22.00 |
| Calcium | 0.850 | 0.700 |
| Available phosphorus | 0.320 | 0.270 |
| Sodium | 0.170 | 0.150 |
| Potassium | 0.957 | 0.855 |
| Digestible lysine | 1.424 | 1.053 |
| Digestible methionine | 0.752 | 0.524 |
| Methionine + Digestible Cystine | 1.067 | 0.816 |
| Digestible threonine | 1.076 | 0.804 |
| Digestible tryptophan | 0.314 | 0.000 |

[1] Basic product composition: Iron sulfate, copper sulfate, zinc oxide, manganese monoxide, sodium selenite, calcium iodide. Guaranteed levels per kg of product: Manganese 140,000 mg, Zinc 120,000 mg, Iron 100,000 mg, Copper 18,000 mg, Iodine 2,000 mg, Selenium 600 mg. [2] Guaranteed levels per kg of product: Vitamin A 40,000,000 IU, Vitamin D3 10,000,000 IU, Vitamin E 80,000 IU, Vitamin K3 10,000.0 mg, Vitamin B12 64,000.0 mg, Vitamin B1 7,200.0 mg, Vitamin B2 24,000.0 mg, Vitamin B6 11,200.0 mg, Folic Acid 4,000.0 mg, Pantothenic Acid 48,000.0 mg, Nicotinic Acid 160,000.0 mg, Biotin 260.0 mg.

The quails were weighed at the beginning and end of each rearing phase (14, 21 and 42 days of age) to determine weight gain per analyzed period. The feed supplied, waste and leftovers in the feeders were considered in calculating feed intake. Thus, feed intake was obtained based on the average consumption per experimental unit within each phase. Feed conversion data were obtained based on feed intake and weight gain per phase analyzed.

Next, two quails per experimental unit were selected at 21 and 42 days of age, subjected to a six-hour solids fast and euthanized to determine carcass and cut yield. Euthanasia was performed by cervical dislocation, followed by bleeding and plucking to obtain absolute weight and yield of hot eviscerated

carcass and the cuts (breast and thigh-drumstick considered as legs). Thus, the carcass and cuts were individually weighed, multiplied by 100 and divided by the average weight of the experimental unit to determine the yield. The observed data were submitted to analysis of variance using the GLM procedure in the SAS statistical program (Statistical Analysis System, 1998) and the means were compared using the Tukey's test with a significance level of 5%.

## RESULTS AND DISCUSSION

Based on the data in Table 2, it appears that there was a significant effect (P<0.05) for weight gain, feed intake and feed conversion in all evaluated periods, with the best results being observed in quails submitted to treatments in which fennel (FEO) and citronella (CEO) essential oils were used to replace antibiotics in their diets.

**Table 2**. Productive performance of European quails submitted to the inclusion of essential oils in the diet to replace zinc bacitracin.

| | Experimental diets | | | | | |
|---|---|---|---|---|---|---|
| | PC | NC | CEO | FEO | P-value | CV (%) |
| | 1 to 14 days of age | | | | | |
| WG | 79.54 c | 41.50 d | 82.51 b | 92.74 a | <.0001 | 2.69 |
| FI | 131.12 a | 108.15 b | 127.24 a | 125.95 a | 0.010 | 2.83 |
| FC | 1.64 b | 2.60 a | 1.54 c | 1.35 d | 0.008 | 3.11 |
| | 14 to 21 days of age | | | | | |
| WG | 118.54 c | 61.33 d | 129.99 b | 132.16 a | <.0001 | 2.15 |
| FI | 229.82 a | 206.04 c | 216.57 b | 211.46 bc | 0.037 | 2.69 |
| FC | 1.93 b | 3.36 a | 1.67 c | 1.59 c | 0.005 | 2.45 |
| | 22 to 42 days of age | | | | | |
| WG | 138.82 b | 126.83 c | 138.82 b | 156.29 a | 0.017 | 2.71 |
| FI | 579.40 b | 763.24 a | 523.19 c | 547.29 bc | 0.043 | 2.98 |
| FC | 4.19 b | 6.02 a | 3.75 c | 3.50 d | 0.002 | 2.84 |

Means followed by different letters on the same line differ from each other by the Tukey's test (P<0.05).
Legend: WG = Weight gain; FI = Feed intake; FC = Feed conversion; PC = Positive control diet; NC = Negative control diet; CEO = Diet with citronella essential oil added; FEO = diet with fennel essential oil added.

The use of fennel (FEO) and citronella (CEO) essential oils provided greater weight gain (WG) and better feed conversion (FC) in quails from 1 to 14 days of age. The worst values for the same variables were observed in quails that received the diet without the addition of essential oils or antibiotics (NC).

The addition of fennel or citronella essential oil provided greater weight gain to the quails from 14 to 21 days of age. The highest feed intake was observed in quails that received the positive control diet (PC) and the lowest intake was observed in quails that received the negative control diet (NC). The best feed conversion was observed in quails that received fennel essential oil in the diet, followed by those that received citronella oil in the diet. The worst feed

conversion was observed when essential oils or antibiotics were not added (NC).

It is observed that the weight gain was the same for the PC and CEO treatments in the phase from 22 to 42 days of age, and the highest weight gain and best feed conversion were obtained when the quails received the FEO treatment instead of the antibiotic. Moreover, the quails of the NC showed higher feed intake in the same analyzed period.

When comparing the results of the use of the two essential oils, it appears that the FEO provided better results in all evaluated phases, representing a weight gain of 12.58% more in relation to the positive control and the CEO treatment. On the other hand, it was identified that the exclusion of essential oils and antibiotics (NC) resulted in the worst productive performance values in all analyzed phases.

These data corroborate the results obtained by Soltan et al. (2008) in analyzing the effect of anise supplementation (fennel) at 0.5 and 0.75 g/kg of feed for broilers, who observed that performance, growth and body weight were better when fennel was included in the broilers' diet. On the other hand, no significant effect was observed for the feed intake and feed conversion variables.

Although including fennel seeds in the diets of broilers did not influence the performance variables in the initial phase (1 to 21 days of age), the authors found greater weight gain and better feed conversion when using 2 to 3 g/kg of ration in the growth and final phases (22 to 42 days) (Mohammed & Abbas, 2009).

It is known that the presence of some pathogenic microorganisms causes epithelial lesions in the intestine of birds, causing a reduction in their use of nutrients, which may have occurred in this study to justify the lower performance of those who did not receive essential oils or antibiotics in the diet.

Even though the quails were not experimentally challenged with any infectious agent during the experimental period, the good performance results observed when citronella or fennel essential oil were included may be a consequence of their preventive action. There are citations in the literature about the use of essential oils from plants with antibacterial, antiparasitic and antioxidant effects (Koiyama et al. 2014; Botsoglou et al. 2010; Giannenas et al. 2005).

The previously mentioned effects probably occur because these substances act in improving the defensive barrier in the intestinal mucosa by reducing the adhesion of pathogenic bacteria to the animal's intestine. This means that the production of toxins by bacteria is not harmful to the cells of the intestinal mucosa, in turn improving the digestion and absorption processes, favoring the maximum use of nutrients (Cardoso & Tessari, 2015).

Furthermore, the two essential oils tested in this research have proven antibacterial action, mainly on gram-positive pathogenic bacteria, as they contain chemical agents in their composition which are similar to the action of most antibiotics used in the formulation of diets in animal production (Silveira, et al. al. 2012).

Table 3 shows that there was a significant effect ($P<0.05$) for the live weight, carcass weight and percentage, and breast and leg percentage variables in the two evaluated periods.

**Table 3**. Carcass and cut yield of quails submitted to inclusion of essential oils in the diet to replace growth promoters.

| | Experimental diets | | | | | |
|---|---|---|---|---|---|---|
| | PC | NC | CEO | FEO | P-value | CV (%) |
| | 21 days of age | | | | | |
| Live weight (g) | 132.20 a | 100.60 b | 136.80 a | 135.00 a | 0.002 | 9.69 |
| Carcass (g) | 68.39 b | 52.05 c | 89.47 a | 90.55 a | 0.007 | 5.74 |
| Carcass (%) | 51.87 b | 52.45 b | 65.68 a | 67.09 a | 0.019 | 5.91 |
| Breast (%) | 44.12 bc | 43.03 c | 47.05 b | 55.14 a | 0.026 | 5.31 |
| Legs (%) | 28.98 a | 23.96 b | 30.91 a | 27.93 a | 0.009 | 9.27 |
| | 42 days of age | | | | | |
| Live weight (g) | 256.56 c | 188.16 d | 285.29 a | 270.98 b | 0.039 | 3.17 |
| Carcass (g) | 163.79 b | 109.37 c | 169.46 b | 181.91 a | 0.006 | 3.29 |
| Carcass (%) | 63.84 a | 58.15 b | 59.41 b | 67.12 a | 0.041 | 3.67 |
| Breast (%) | 39.91 a | 36.44 b | 40.08 a | 40.34 a | 0.043 | 4.69 |
| Legs (%) | 26.98 a | 23.19 b | 27.80 a | 25.84 a | 0.038 | 4.20 |

Means followed by different letters on the same line differ from each other by the Tukey's test ($P<0.05$).

The highest live weight values at 21 days were observed in treatments with the inclusion of fennel or citronella essential oils. The same pattern of results was observed when carcass and cut (breast and legs) yields were calculated. The quails that received the diet without the insertion of oils or antibiotics showed the worst results for the live weight, carcass (g), breast (%) and leg (%) variables during this period.

The effect of treatments on the analyzed variables remained similar at 42 days to that of the previous analyzed phase; however, the quails that received the antibiotic showed similar results for the carcass (g), breast (%) and leg (%) variables to the quails that consumed the diet with citronella oil. On the other hand, quails that received fennel oil in the diet continued to present the best values for the analyzed variables, and those that received the diet without the presence of essential oils or antibiotics maintained the worst results for all of the analyzed variables.

There is limited information on the mechanism of action of essential oils on muscle tissue; however, it is believed that the chemical composition of the oils may have positively influenced the digestion and absorption of nutrients, which probably should have favored a better nutritional intake to the muscle tissue, resulting in higher live and carcass weights, and consequently higher cut yield.

Hernandez et al. (2004) described the chemical composition of fennel essential oil and reported anethole, enchona, and acharhol as the main agents capable of stimulating digestive functions, enteric circulation and helping the liver to eliminate toxic compounds, which probably must have occurred in this study to provide better results when fennel essential oil was included in the quail's diet to replace the antibiotic.

On the other hand, citronella essential oil has cytonellal, geraniol, elemol and citronellol, which are chemical constituents with proven action on

pathogenic microorganisms and can cause enteritis in animals, and consequently less digestion and absorption of nutrients that can be used to synthesize body proteins. Such compounds induce oxidation of lipids in the cell wall of pathogenic bacteria and fungi, in turn eliminating agents capable of producing toxins and causing damage to enterocytes, which reduces the proliferation of pathogenic microorganisms in the intestine of animals and favors the absorption of nutrients (Veloso et al. 2012). Once intestinal health is maintained, the molecular mechanisms of muscle fiber growth can be more efficiently favored and activate the development of muscle tissue as a whole (Wen et al. 2014).

In conclusion, the use of fennel or citronella essential oils to replace zinc bacitracin in the diet of European quails at different developmental stages provides better performance, carcass and cut yield. When compared, the fennel essential oil is more efficient than citronella oil.

## REFERENCES

AL-SNAFI, A.E. The chemical constituents and pharmacological effects of Foeniculum vulgare – A review. **Journal of Pharmacy**, v. 8, n. 5, p.81-96, 2018.

BOTSOGLOU, E.; GOVARIS A.; CHRISTAKI E.; BOTSOGLOU, N. Effect of dietary olive leaves and/or α-tocopheryl acetate supplementation on microbial growth and lipid oxidation of turkey breast fillets during refrigerated storage. **Food Chemistry**, v.121, p.17-22, 2010.

CARDOSO, A.L.S.P.; TESSARI, E.N.C. Interação entre imunidade e nutrição das aves: revisão de literatura. **Revista Científica de Medicina Veterinária**, v.24, 2015.

GIANNENAS I.; FLOROU-PANERI P.; BOTSOGLOU N.A.; CHRISTAKI, E.; SPAIS, A.B. Effect of supplementing feed with oregano and/ or α-tocopheryl acetate on growth of broiler chickens and oxidative stability of meat. **Journal Animal Feed Science**, v.14, n.3, p.521-535, 2005.

HERNANDEZ, F.; MADRID J.; GARCÍA, V.; ORENGO, J.; MÉGIAS, M.D. Influence of two plant extracts on broilers performance, digestibility and digestive organ size. **Poultry Science**, v.83, p.169-174, 2004.

KOIYAMA, N.T.G.; ROSA, A.P.; PADILHA, M.T.S.; BOEMO, L.S.; SCHER, A.; MELO, A.M.S.; FERNANDES, M.O. Desempenho e rendimento de carcaça de frangos de corte alimentados com mistura de aditivos fitogênicos na dieta. **Pesquisa Agropecuária brasileira**, v.49, n.3, p.225- 231, 2014.

LEE, Y. H.; CHOI, C. H.; KIM, S.W.; YUN, J.G.; CHANG, S.W.; KIM, Y.S.; HONG, J.K. Chemical pesticides and plant Essential oils for disease control of tomato bacterial wilt. **The Plant Pathology Journal**, v.28, p.32-39, 2012.

LEMOS, M.J.; CALIXTO, L.F.L.; TORRES-CORDIDO, K.A.A.; REIS, T.L. Uso de aditivo alimentar equilibrador da flora intestinal em aves de corte e de postura. **Arquivos do Instituto Biológico**, v.83, p.1-7, 2016.

MOHAMMED, A.A.; ABBAS, R.J. The effect of using fennel seeds (*Foeniculum vulgare L.)* on productive performance of broiler chickens. **International Journal of Poultry Science**, v.7, p.642-644, 2009.

NOGUEIRA, W.C.L.; RIPPEL, D. N.; ALMEIDA, A.C.; SANTOS, E.V.; WENCESLAU, R.R.; FERREIRA, F. Lemon grass essential oil on productive characteristics of broiler chickens. **Acta Veterinária Brasílica**. v.11, n.2, p.93-97, 2017.

REIS, M. P.; RODRIGUES, P. B.; CANTERELLI, V. S.; MENEGHETTI, C.; GARCIA JÚNIOR, A.A.P.; LIMA, R.R.; FASSANI, E.J.; NAVES, L.P. Níveis de bacitracina de zinco como melhorador do desempenho de frangos de corte. **Ciência Rural**, v.44, n.6, p.1093-1099, 2014.

SILVA, J.H.V.; COSTA, F.G.P. **Tabela para codornas japonesas e europeias**. Jaboticabal: Funep, 107p. 2009.

SILVEIRA, S.M.; CUNHA JÚNIOR, A.; SCHEUERMANN, G.N.; SECCHI, F.L.; VERRUK, S.; KROHN, M.; VIEIRA, C.R.W. Composição química e atividade antibacteriana dos óleos essenciais de *Cymbopogon winterianus* (citronela), *Eucalyptus paniculata* (eucalipto) e *Lavandula angustifolia* (lavanda). **Revista do Instituo Adolf Lutz** , v.71, n.3, 2012.

SOLTAN, M.A.; SHEWITA, R.S.; EL-KATCHA, M.I. Effect of dietary anise seeds supplementation on growth performance, immune response, carcass traits and some blood parameters of broiler chickens. **International Journal of Poultry Science**, v.7, p.1078-1088, 2008.

STATISTICAL ANALYSIS SYSTEM INSTITUTE - SAS. *SAS users guide*: statistics. Cary: SAS, 1998. 956p.

TEIXEIRA, E.N.M.; SILVA, J.H.V.; COSTA, F.G.P.; SILVA, C.T.; GOULART, C.C.; MELO, T.S. Óleo essencial de erva-doce na ração de frangos de corte alojados em cama nova e reciclada. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.65, n.3, p.874-884, 2013.

VERMA, R.S.; VERMA, S.K; TANDON, S.; PADALIA, R.C.; DAROKAR, M.P. Chemical composition and antimicrobial activity of Java citronella (*Cymbopogon winterianus* Jowitt ex Bor) essential oil extracted by different methods. **Journal of essential Oil Research**, v.32, n.5, p. 449-455, 2020.

VELOSO, R.A.S.; CASTRO, H.G.; CARDOSO, D.P.; SANTOS, G.R.; BARBOSA, L.C.A.; SILVA, K.P. Composição e fungitoxicidade do óleo essencial de capim citronela em função da adubação orgânica. **Pesquisa Agropecuária Brasileira**, v.47, n.12, p.1707-1713, 2012.

WEN, C.; CHEN, X.; CHEN, G.Y.; CHEN, Y.P.; ZHO, Y.M.; WANG, T. Methionine improves breast muscle growth and alters myogenic gene expression in broilers. **Journal Animal Science**, v.92, p.1068-1073, 2014.

ISSN 1519 9940