2024, Scienceline Publication
World's Veterinary Journal
World Vet J, 14(1): 91-96.
ISSN 2322-4568

DOI: https://dx.doi.org/10.54203/scil.2024.wvj12
PII: S232245682400012-14

Production Performance and Some Biochemical Traits of Layer Hens Fed on Date Palm Kernel Supplementation

Zahira A. Al-Zuhairi[1], Afrah S. Mhyson[2], and Basima J. Mohammed[1]

[1]*College of Veterinary Medicine, University of Al-Qadisiyah, Iraq*
[2]*College of Dentistry, University of Al-Qadisiyah, Iraq*

*Corresponding author's Email: mtqr86@gmai.com

ORIGINAL ARTICLE
Received: January 12, 2024
Revised: February 19, 2024
Accepted: February 26, 2024
Published: March 25, 2024

ABSTRACT

To enhance the well-being and productivity of poultry, researchers have conducted investigations into various botanical sources, including date palm kernel, and their bioactive components. The present investigation was conducted to assess the productive performance and certain biochemical characteristics of layer hens that were administered date palm kernel supplementation in their diet. To this end, 40 ISA Brown laying hens (48 weeks old) were used in the current study. The adaptation phase for the chickens lasted for 10 days before the initiation of the experiment. The study lasted 8 weeks. The chickens were then randomly assigned into two groups of 20, with 4 replications (5 chickens per replication). Chickens in the treatment group received 5% of dry matter ground date palm kernel (GDPK), as an additive to the basal diet, and the control group (CL) chickens were fed the basal diet. The eggs were collected daily during the study. At the end of weeks 1, 2, 4, and 6 of the study, egg production percentage, egg weight, and the feed conversion ratio were measured. At the end of the experiment, blood samples were collected to measure the serum levels of glucose, total protein, cholesterol, creatinine, and uric acid. The study findings revealed significant increases in the daily egg production percentage and egg weight during the experiment in the GDPK group, compared to the CL group. The feed conversion ratio recorded significant decreases in the GDPK group when compared to the CL group. Furthermore, the findings indicated significant increases in the serum total protein and significant decreases in the glucose, cholesterol, creatinine, and uric acid concentrations in the GDPK group, compared to the CL group. In conclusion, the results indicated the positive effects of adding ground date palm kernel to the diet of layers on production performance, such as egg weight, conversion ratio, and some biochemical traits, including total protein, glucose, cholesterol, creatinine, and uric acid.

Keywords: Date palm, Egg production, Feed additive, Kernel, Laying hen

INTRODUCTION

The rapid growth of the world population has led to a sharp increase in the demand for egg production. To meet this demand, there is a critical need for substantial improvements in hen genetics, nutrition, and husbandry practices (Guerrero-Legarreta, 2010; Küçükyilmaz et al., 2012). In the poultry industry, it is essential to explore cost-effective methods to boost egg production while maintaining high quality. Therefore, there has been a demand from consumers for healthier eggs with high quality (Wang et al., 2017; Marelli et al., 2021).

The global chicken business is one of the most rapidly expanding agricultural sectors. There have been several recent threats to the poultry industry, including rising worldwide populations, altered climates, a lack of feedstuffs, a weak economy, and new illnesses (El-Sabrout et al. 2019). Chicken egg is a complete food since it has both organic and inorganic constituents and includes a significant amount of water (~75% water; El-Sabrout et al., 2022).

Liquid egg white, freeze-dried egg powder, and egg white protein are some innovative egg products that have gained popularity among customers (Perić et al., 2011). Despite the common belief that eating eggs can raise blood cholesterol, several clinical and epidemiological studies have established no such correlation (Alagawany et al., 2018; Réhault-Godbert et al., 2019).

In order to improve chicken health and production, scientists have studied some botanical sources, such as date palm kernel, and their bioactive constituents. Poultry farms are beginning to embrace the use of these compounds because of their nutritional significance, medicinal capabilities, and lack of residual effects. Date palm kernel, for instance, has long been used in chicken feeds to maintain chickens' wellness and maximize productivity (El-Husseiny et al., 2008; Tareen et al., 2017). Date palm kernel possesses beneficial activities, such as anti-inflammatory and antibacterial properties, attributed to its bioactive constituents that significantly influence physiological functioning (El-Husseiny et al., 2008; Saki et al., 2014; Abo Ghanima et al., 2020).

To cite this paper: Al-Zuhairi ZA, Mhyson AS, and Mohammed BJ (2024). Production Performance and Some Biochemical Traits of Layer Hens Fed on Date Palm Kernel Supplementation. *World Vet. J.,* 14 (1): 91-96. DOI: https://dx.doi.org/10.54203/scil.2024.wvj12

The current study was performed to study the efficiency of production performance and some biochemical traits of layer hens fed with date palm kernel supplementation.

MATERIALS AND METHODS

Ethical approval

The current study was conducted according to the ethical guidelines College of Veterinary Medicine, University of Al-Qadisiyah, Iraq.

Date palm collection

The date palm kernel was collected during the flowering period at the end of March month before pollination from male palm trees growing in the Al-Qadisiyah agriculture department, Iraq.

Date palm chemical composition

Crude protein, crude fiber, crude fat, ash, and total sugars for date palm kernel grains were determined according to AOAC (Bardaa et al., 2016). The concentrations of calcium (Ca), potassium (K), iron (Fe), and magnesium (Mg) were determined using Atomic Absorption Spectrometry (AAS) according to Hosseinzadeh et al. (2015).

Animals and study procedure

The study included 40 ISA Brown laying hens (48 weeks old). The chickens were randomly assigned into two groups of 20 hens with 4 replicates of 5 chickens per each. Before the experiment, the chickens were left for 10 days to adapt to the experimental environment. These groups were the treatment group that received 5% of dry matter ground date palm kernel (GDPK), as an additive to a standard diet (Table 1), until the end of the experiment (8 weeks), and a control group (CL) that received basal diet only.

Table 1. The chemical analysis and composition of diet in layer chickens in present study

Ingredients	Percentage
Corn	40
Soybean meal	20
Rice	25
Wheat bran	10.7
Lime stone	2
Premix 1	0.3
NaCl	0.5
Mono-calcium phosphate	1.5
Total	100
Chemical analysis	
CP	18.16
EE	2.65
CF	3.44
Ash	12.2
Ca	3.82
Available P	0.28
Lysine	0.7
Methionine	0.2
ME (Kcal/kg)2	2630

Premix 1: Contained 4540 mg/kg of Fe, 5000 mg/kg of Cu, 3400 mg/kg of Mn, 43 mg/kg of Co, 6000 mg/kg of Zn, 140 mg/kg of Se, 3600 kIU/kg of vitamin A, 360 kIU/kg of vitamin D, and 3 kIU/kg of vitamin E; CP: Crude protein, CF: Crude fiber, EE: Ether extract. The diet was balanced according to the last commercial recommendation of ISA Brown laying chickens' catalog.

Sampling

The produced eggs (n = 20) were collected daily during the study. Eggs collected at the end of weeks 1, 2, 4, and 6 were used to measure the egg quantity, egg weight, and the efficiency of the feed conversion ratio (FCR). At the end of the experiment, blood samples (2 ml) were collected from the wing vein of all chickens in a tube without anticoagulant for measuring the serum levels of glucose, total protein, cholesterol, creatinine, and uric acid with a commercial kit according to manufacturer instruction.

Production parameters, egg quality traits, and feed conversion ratio

The initial and final body weights were measured using a digital balance with an accuracy of ±0.5 g at 78 and 84 weeks of age for each replicate within the treatment. The egg number and weight were recorded daily during the experimental period from 78 to 84 weeks of age. Egg weights were recorded daily, while egg mass (g/hen) was calculated by multiplying the laid eggs numbers and weight (g) for all replicates within each treatment. Egg weights were recorded on a daily basis, while egg mass (g/hen) was calculated by multiplying the laid egg numbers and their respective weights (g) for all replicates within each treatment. Feed consumption (g/hen/d) was recorded weekly for each replicate, and FCR was measured as the ratio of feed in grams to the weight of eggs produced. A total of 140 normal eggs were randomly collected from eggs laid in the last three days (4 groups × 7 replicates × 5 eggs) to determine the external and internal egg quality traits.

Statistical analysis

GraphPrism v7 and SPSS software were used to analyze and present data. The sample t-test was used to analyze the data. The standard deviation of the mean was utilized to display mean data in graphs and tables. P values less than 0.05 were considered for significant differences.

RESULTS

The study findings revealed significant increases in the daily egg production percentage for all examined weeks in the GDPK group, compared to the CL group ($p < 0.05$, Figure 1). Moreover, egg weight was significantly higher at all tested week points in the GDPK group than that of the CL group ($p < 0.05$, Figure 2). Moreover, the feed conversion rate recorded significant decreases in the GDPK group when compared with this finding from the CL group ($p < 0.05$, Table 4 and Figure 3). Furthermore, the findings indicated significant increases in the serum total protein ($p < 0.05$) and significant decreases in the glucose, cholesterol, creatinine, and uric acid concentrations in the GDPK group when compared with these findings from the CL group ($p < 0.05$; Table 5 and Figure 4).

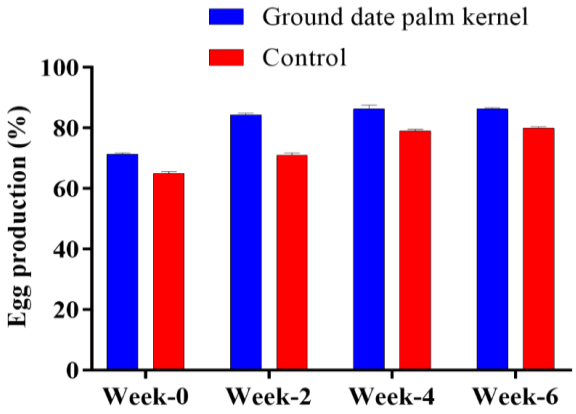

Figure 1. Daily egg production of laying hens fed ground date palm kernel

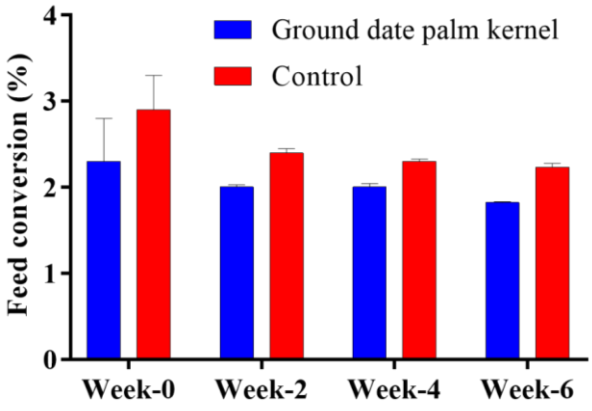

Figure 3. Feed conversion efficiency of laying hens fed ground date palm kernel

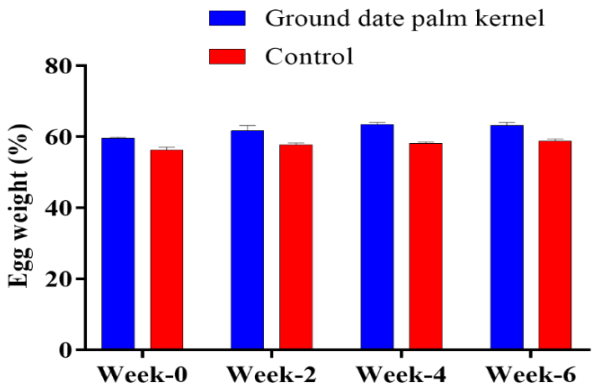

Figure 2. Egg weight of laying hens fed ground date palm kernel

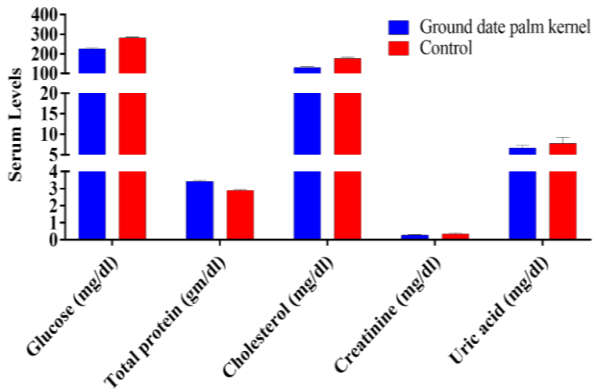

Figure 4. Serum biochemical parameters of laying hens fed ground date palm kernel

DISCUSSION

Contemporary poultry lines have been genetically engineered to optimize both meat and egg production. However, their heightened metabolic activity leads to an increased production of intracellular free radicals. These free radicals pose the risk of inducing oxidative stress, triggering inflammation, and disrupting various cellular processes (Hosseinzadeh et al., 2015). Numerous botanical items and their bioactive substances have been studied for their potential to eliminate free radicals and restore crucial cellular functions essential for poultry health and production. Plant medicinal seeds, such as date palm kernel, are examples of botanical constituents gaining attention in poultry farms for their nutritional quality, therapeutic capabilities, and residue-free nature (Hosseinzadeh et al., 2015; Chen et al., 2018).

The findings from the present study revealed a significant increase in both egg production and egg weight with the inclusion of GDPK as a feed additive. These effects became evident early in the experiment, specifically during the initial week of treatment. While limited information is available regarding the impact of the kernel on egg production, numerous researchers have explored various herbal, plant, and seed preparations in this context. These preparations often contain components known for their diverse health benefits, including antioxidative and anti-inflammatory activities (Alkhoori et al., 2022).

The seeds of the fenugreek plant have been employed for medicinal purposes for many years, primarily owing to their antimicrobial and anti-inflammatory characteristics (Adil et al., 2015). For laying hens mainly, Samani et al. (2020) found that 1% fenugreek increased feed intake and yolk color, especially in the latter cycle of egg production. Using 0.4% fenugreek in hen diets increased both egg output and egg quality. Ginger roots utilized as a medicinal plant all over the globe are another instance of a nutritional approach for increasing egg production. The gingerols, zingerone, and date palm kernel help beneficial microbiota and antioxidant defenses. Supplementing layer diets with ginger powder (10-15gm/kg) increased egg production and serum antioxidant capacity (Zhao et al., 2011). Several scientists and plant breeders throughout the globe have lately been interested in pumpkin seeds because of their potential as both a food source and medicine. They are abundant in saturated fatty acids and omega-3 fatty acids (Bardaa et al., 2016). According to Martínez et al. (2012), including 10% pumpkin into a layer hen diet improves beneficial fatty acids while lowering total cholesterol and detrimental fatty acids in the content of eggs.

In addition to the previously mentioned benefits, date seeds are rich in bioactive compounds with antioxidative and anti-inflammatory properties. Specifically, extracts from Ajwa date seeds have been recently discovered to exhibit exceptional antioxidant capabilities, comparable to those found in ascorbic acid (Anwar et al., 2022). This highlights the potential health-promoting attributes of date seeds and their significance as a source of natural antioxidants (Anwar et al., 2022). Because of their high phenolic component content, date seeds have also been studied for their potential antioxidant benefits. Salomón-Torres et al. (2019) observed that the polyphenolic composition of 'Medjool' date seeds is 10 magnitudes greater than that of the pulp. Research has demonstrated the antioxidant properties of date seeds, which have been assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method. The presence of various phenolic compounds, including tannins, saponins, flavonoids, coumarins, and anthraquinones, leads to these antioxidant characteristics. These bioactive molecules play a vital role in neutralizing free radicals and protecting cells from oxidative damage, making date seeds a promising natural source of antioxidants. Date palm kernel polyphenolic compounds could deliver significant antioxidants, helping to promote health and stave against illness in egg-laying hens. Employing the DPPH technique, Bentrad and Gaceb-Terrak (2020) discovered that extracts of date seeds had antioxidant properties. Compared to other antioxidant compounds, the extract of date palm kernel showed the greatest free radical inhibitory effectiveness. The phenolic chemicals found in date seeds are responsible for the antioxidant qualities of seeds since they efficiently donate hydrogen to DPPH radicals. These phenolic components include phenolic acids, flavonoids, and catechin tannins. Hilary et al. (2021) indicated the total polyphenol composition of date seed preparations and found significant increases in the phenolic compounds after consuming these preparations. Phenolic compounds prevent oxidative destruction of DNA, proteins, and lipids by neutralizing free radicals.

Due to the presence of these phenolic compounds in the date kernel, bird health and maximizing performance could have been improved in the current study, leading to an increase in the performance of the tested chickens. Date palm kernel contains bioactive constituents with beneficial impacts on physiological functioning and therapeutic qualities. Phytobiotics, tannins, phenols, flavonoids, and essential oils are found in eggs, and they serve several purposes in the birds' bodies. Feed additives such as date palm kernel have positive effects on egg weight, ovary features, and lowering yolk trimethylamine contents (López-Sobaler et al., 2017; Abolhasani Zadeh et al., 2022; Rohmah et al., 2022; Margiana et al., 2022; Arif et al., 2023).

CONCLUSION

The study results indicate the positive effects of adding ground date palm kernel to the diet of layers on production performance such as egg weight, conversion ratio, and some biochemical traits including total protein, glucose, cholesterol, creatinine, and uric acid. Therefore, more study is needed to evaluate the effects of date palm kernel on chicken production and biochemical traits.

DECLARATIONS

Funding

There was no particular grant from any funding source in the public, commercial, or not-for-profit sectors for this research.

Competing interests

The authors declare that they have no conflict of interest.

Authors' contributions

Zahira A. Al-Zuhairi, Afrah S.Mhyson, and Basima J. Mohammed, designed, drafted the article, and revised it critically for important intellectual content; Zahira A. Al-Zuhairi, and Afrah S.Mhyson, analysis, and interpretation. All the authors reviewed the final draft of article and agreed the content before submission.

Availability of data and materials

The authors will provide all necessary data to the editor upon request.

Ethical considerations

All authors have reviewed the ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and falsification, multiple publishing and submission, and redundancy)

REFERENCES

Abo Ghanima MM, Elsadek MF, Taha AE, Abd El-Hack ME, Alagawany M, Ahmed BM, Elshafie MM, and El-Sabrout K (2020). Effect of housing system and rosemary and cinnamon essential oils on layers performance, egg quality, haematological traits, blood chemistry, immunity, and antioxidant. Animals, 10(2): 245. DOI: https://www.doi.org/10.3390/ani10020245

Abolhasani Zadeh F, Bokov DO, Salahdin OD, Abdelbasset WK, Abed Jawad M, Kadhim MM, Qasim MT, Kzar HH, Al-Gazally ME, Mustafa YF et al. (2022). Cytotoxicity evaluation of environmentally friendly synthesis Copper/Zinc bimetallic nanoparticles on MCF-7 cancer cells. Rendiconti Lincei. Scienze Fisiche e Naturali, 33: 441-447. Available at: https://link.springer.com/article/10.1007/s12210-022-01064-x

Adil S, Qureshi S, and Pattoo RA (2015). A review on positive effects of fenugreek as feed additive in poultry production. International Journal of Poultry Science, 14(12): 664-669. DOI: https://www.doi.org/10.3923/ijps.2015.664.669

Alagawany M, Farag MR, Dhama K, and Patra A (2018). Nutritional significance and health benefits of designer eggs. World's Poultry Science Journal, 74(2): 317-330. DOI: https://www.doi.org/10.1017/S0043933918000041

Alkhoori MA, Kong ASY, Aljaafari MN, Abushelaibi A, Erin Lim SH, Cheng WH, Chong CM, and Lai KS (2022). Biochemical composition and biological activities of date palm (*Phoenix dactylifera* L.) seeds: A review. Biomolecules, 12(11): 1626. DOI: https://www.doi.org/10.3390/biom12111626

Anwar S, Raut R, Alsahli MA, Almatroudi A, Alfheeaid H, Alzahrani FM, Ali Khan A, Allemailem KS, Almatroodi SA, and Rahmani AH (2022). Role of Ajwa date fruit pulp and seed in the management of diseases through *in vitro* and in silico analysis. Biology, 11(1): 78. DOI: https://www.doi.org/10.3390%2Fbiology11010078

Arif A, Alameri AA, Bin Tariq U, Ansari SA, Ibrahim Sakr H, Qasim MT, Aljoborae FFM, Ramírez-Coronel AA, Jabbar HS, Gabr GA et al. (2023). The functions and molecular mechanisms of Tribbles homolog 3 (TRIB3) implicated in the pathophysiology of cancer. International Immunopharmacology, 114: 109581. DOI: https://www.doi.org/10.1016/j.intimp.2022.109581

Bardaa S, Ben Halima N, Aloui F, Ben Mansour R, Jabeur H, Bouaziz M, and Sahnoun Z (2016). Oil from pumpkin (*Cucurbita pepo* L.) seeds: Evaluation of its functional properties on wound healing in rats. Lipids in Health and Disease, 15: 73. DOI: https://www.doi.org/10.1186/s12944-016-0237-0

Bentrad N and Gaceb-Terrak R (2020). Evaluation of the level of biomolecules isolated from date palm seeds (*Phoenix dactylifera*) and *in vitro* antioxidant property. BioMedicine, 10(2): 23-29. DOI: https://www.doi.org/10.37796%2F2211-8039.1017

Chen Y, Chen H, Li W, Miao J, Chen N, Shao X, and Cao Y (2018). Polyphenols in Eucalyptus leaves improved the egg and meat qualities and protected against ethanol-induced oxidative damage in laying hens. Journal of Animal Physiology and Animal Nutrition, 102(1): 214-223. DOI: https://www.doi.org/10.1111/jpn.12680

El-Husseiny OM, Abd-Elsamee MO, Hassane MI, and Omara II (2008). Response of egg production and egg shell quality to dietary vegetable oils. International Journal of Poultry Science, 7(10): 1022-1032. Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=8549cf2279015539a1fcfbe5100355e72ee1109f

El-Sabrout K, Ahmad S, and El-Deek A (2019). The *In ovo* feeding technique as a recent aspect of poultry farming. Journal of Animal Health and Production, 7(4): 126-130. DOI: http://www.doi.org/10.17582/journal.jahp/2019/7.4.126.130

El-Sabrout K, Aggag S, and Mishra B (2022). Advanced practical strategies to enhance table egg production. Scientifica, 2022: 1393392. DOI: https://www.doi.org/10.1155/2022/1393392

Guerrero-Legarreta I (2010). Handbook of poultry science and technology, secondary processing. Handbook of poultry science and technology, Vol. II. John Wiley & Sons, Inc., Hoboken, NJ, USA, pp. 3-601. Available at: https://www.agropustaka.id/wp-content/uploads/2020/04/agropustaka.id_buku_Handbook-of-Poultry-Science-and-Technology-Secondary-Processing-Volume-2.pdf

Hilary S, Kizhakkayil J, Souka U, Al-Meqbaali F, Ibrahim W, and Platat C (2021). *In vitro* investigation of polyphenol-rich date (*Phoenix dactylifera* L.) seed extract bioactivity. Frontiers in Nutrition, 8(8): 667514. DOI: https://www.doi.org/10.3389%2Ffnut.2021.667514

Hosseinzadeh S, Jafarikukhdan A, Hosseini A, and Armand R (2015). The application of medicinal plants in traditional and modern medicine: A review of *Thymus vulgaris*. International Journal of Clinical Medicine, 6(9): 635-642. DOI: http://www.doi.org/10.4236/ijcm.2015.69084

Küçükyilmaz K, Bozkurt M, Herken EN, Çinar M, Çatl AU, Bintaş E, and Çöven F (2012). Effects of rearing systems on performance, egg characteristics and immune response in two layer hen genotype. Asian Australasian Journal of Animal Sciences, 25(4): 559-568. DOI: https://www.doi.org/10.5713%2Fajas.2011.11382

López-Sobaler AM, Vizuete AA, and Ortega RM (2017). Role of the egg in the diet of athletes and physically active people. Nutricion Hospitalaria, 34(Suppl 4): 31-35. DOI: https://www.doi.org/10.20960/nh.1568

Marelli SP, Madeddu M, Mangiagalli MG, Cerolini S, and Zaniboni L (2021). Egg production systems, open space allowance and their effects on physical parameters and fatty acid profile in commercial eggs. Animals, 11(2): 265. DOI: https://www.doi.org/10.3390/ani11020265

Margiana R, Alsaikhan F, Al-Awsi GRL, Patra I, Sivaraman R, Fadhil AA, AL-Baghdady HFA, Qasim MT, Hameed NM, Mustafa YF et al. (2022). Functions and therapeutic interventions of non-coding RNAs associated with TLR signaling pathway in atherosclerosis. Cellular Signalling, 100: 110471. DOI: https://www.doi.org/10.1016/j.cellsig.2022.110471

Martínez Y, Valdivié M, Solano G, Estarrón M, Martínez O, and Córdova J (2012). Effect of pumpkin (*Cucurbita maxima*) seed meal on total cholesterol and fatty acids of laying hen eggs. Cuban Journal of Agricultural Science, 46(1): 73-78. Available at: http://www.cjascience.com/index.php/CJAS/article/view/85

Perić L, Rodić V, and Milošević N (2011). Production of poultry meat and eggs as functional food: Challenges and opportunities. Biotechnology in Animal Husbandry, 27(3): 511-520. DOI: https://www.doi.org/10.2298/BAH1103511P

Réhault-Godbert S, Guyot N, and Nys Y (2019). The golden egg: Nutritional value, bioactivities, and emerging benefits for human health. Nutrients, 11(3): 684. DOI: https://www.doi.org/10.3390/nu11030684

Rohmah MK, Salahdin OD, Gupta R, Muzammil K, Qasim MT, Al-Qaim ZH, Fadhil Abbas N, Abed Jawad M, Yasin G, Mustafa YF et al. (2022). Modulatory role of dietary curcumin and resveratrol on growth performance, serum immunity responses, mucus enzymes activity, antioxidant capacity and serum and mucus biochemicals in the common carp, Cyprinus carpio exposed to abamectin. Fish & Shellfish Immunology, 129: 221-230. DOI: https://www.doi.org/10.1016/j.fsi.2022.08.042

Saki AA, Aliarabi H, Siyar SAH, Salari J, and Hashemi M (2014). Effect of a phytogenic feed additive on performance, ovarian morphology, serum lipid parameters and egg sensory quality in laying hen. Veterinary Research Forum, 5(4): 287-293. Available at: https://pubmed.ncbi.nlm.nih.gov/25610580/

Salomón-Torres R, Ortiz-Uribe N, Valdez-Salas B, Rosas-González N, García-González C, Chávez D, Chávez D, Córdova-Guerrero I, Díaz-Rubio L, Haro-Vázquez MP et al. (2019). Nutritional assessment, phytochemical composition and antioxidant analysis of the pulp and seed of medjool date grown in Mexico. PeerJ, 7(7): e6821. DOI: https://www.doi.org/10.7717%2Fpeerj.6821

Samani SK, Ghorbani MR, Fayazi J, and Salari S (2020). The effect of different levels of fenugreek (*Trigonella foenum-graecum* L.) powder and extract on performance, egg quality, blood parameters and immune responses of laying hens in second production cycle. Veterinary Research Forum, 11(1): 53-57. DOI: https://www.doi.org/10.30466/vrf.2019.80961.2072

Tareen MH, Wagan R, Siyal FA, Babazadeh D, Bhutto ZA, Arain MA, and Saeed M (2017). Effect of various levels of date palm kernel on growth performance of broilers. Veterinary World, 10(2): 227-232. DOI: https://www.doi.org/10.14202/vetworld.2017.227-232

Wang J, Yue H, Wu S, Zhang H, and Qi G (2017). Nutritional modulation of health, egg quality and environmental pollution of the layers. Animal Nutrition, 3(2): 91-96. DOI: https://www.doi.org/10.1016/j.aninu.2017.03.001

Zhao X, Yang ZB, Yang WR, Wang Y, Jiang SZ, and Zhang GG (2011). Effects of ginger root (*Zingiber officinale*) on laying performance and antioxidant status of laying hens and on dietary oxidation stability. Poultry Science, 90(8): 1720-1727. DOI: https://www.doi.org/10.3382/ps.2010-01280