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***Original Article***

# Effect of Adding Different Levels of Maca Root (*Lepidium Meyenii)* to the Diet on the Productive Performance of Broilers Exposed to Oxidative Stress

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**Abstract**

This experiment was conducted in the poultry field of the Department of Animal Production, College of Agriculture, Al-Qasim Green University, Iraq, for the period from 1/10/ 2021 to 4/11/ 2021. The current study aimed to use different levels of maca roots (*Lepidium meyenii*) to reduce the effects of experimentally-induced oxidative stress by using hydrogen peroxide ($H_2O_2$) in broiler chickens. In the present experiment, 225 unsexed broiler chicks (Ross 308) were used, distributed randomly to 15 cages, with five experimental treatments for each treatment of 45 birds, and each treatment included three replicates for each replicate of 15 birds. The experimental treatments were as follows: the first treatment was considered as the control group (basic diet + drinking water free of $H_2O_2$). The second group: basic diet and water supplemented with 0.5% $H_2O_2$ at a concentration of 0.5%. The third group: adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$. The fourth group: adding 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$. The fifth group: adding 2 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$. The most important results of the study can be summarized as follows: the recorded data showed significant superiority ($P \leq 0.05$) for the first, third, fourth, and fifth treatments in the average live body weight in the fifth week and the total weight gain compared to the second treatment. In addition, the first, fourth, and fifth treatments revealed the best cumulative food conversion ratio and the best productivity index measure, with a significant difference ($P \leq 0.05$) compared to the second treatment.

**Keywords:** Maca root, Productive performance, Broiler, Oxidative stress

## 1. Introduction

Oxidative stress is an imbalance between free radicals resulting from biological activities and the defensive ability of antioxidants in the body, accompanied by an increase in fat oxidation, which results in disruptive damage to various tissues and a decrease in the immune susceptibility to diseases. Antioxidants treat tissue damage as well as prevent the generation of free radicals generated as a result of various vital activities in the body or slow them down, so they constitute a line of defense against the disruptive activity of free radicals in terms of their generation or chain reactions (1-3). The chance of exposure to free radicals increases with the organ's activity. The organs and tissues characterized by high efficiency have a higher chance of exposure to free radicals. Physiological and structural factors increase the likelihood of tissues and biomolecules being exposed to oxidative damage, including the amount of long-chain unsaturated fatty acids (4). There are several types of antioxidants: synthetic, such as some vitamins, which were noted to have a protective role against oxidation processes caused by free radicals (5); and natural, such as medicinal herbs. Among these plants is the root of the maca plant, scientifically known as Lepidium meyenii, a tuberous root plant belonging to the Brassicaceae family, from which cauliflower and broccoli are descended. It is native to South America, where it grows in the high mountains of Peru, and it has been used in the field of herbal medicine since 1843. It is one of the most medicinal plants, rich in antioxidants that protect cells from mutations and damage caused by free radicals. In addition, it contains large amounts of vitamins and is very rich in flavonoids that protect against many diseases (6, 7). Likewise, the roots of the maca plant are rich in the content of amino acids, essential fatty acids, polysaccharides, and mineral elements, such as iron, calcium, zinc, copper, and potassium (8).

Moreover, its effectiveness lies in the fact that it contains compounds N-benzyl-palmitamide, glucosinolates, phenolics, and benzyl isothiocyanate (9). Maca root has many medical effects and uses, where it is used as an antioxidant (10) and has a major role in stimulating the immune system (11). It affects sexual potency and increases fertility through its impact on sex hormones and their receptors (12), and it plays a role in improving the productive performance of poultry (13, 14). Based on the foregoing and in the absence of a local study on maca roots, this experiment aimed to use different levels of maca roots to reduce the effect of oxidative stress-induced experimentally using hydrogen peroxide $H_2O_2$, in addition to knowing the best levels of maca roots that can be used in poultry diets.

## 2. Materials and Methods

This study was conducted in the poultry field of the Department of Animal Production, College of Agriculture, Al-Qasim Green University, Iraq, from 1/10/2021 to 4/11/ 2021. In the experiment, 225 unsexed one-day-age broiler chicks Ross 308 from Al-Anwar hatchery were used in Babylon province. They were randomly distributed to 15 cages with five experimental treatments for each treatment of 45 birds, and each treatment included three replicates for each replicate of 15 birds. The chicks were raised in the cages on a bed of white sawdust with a thickness of 7 cm. The feed was provided to the birds freely, as it was provided a starter diet from the age of 1-10 days, a growth diet from 11-21 days, and a final diet from 22-35 days (Table 1). The experimental treatments were as follows: The first treatment = was represented by the control treatment (basic ration + drinking water free of $H_2O_2$), the second treatment = a standard diet and water added to it $H_2O_2$ at a concentration of 0.5%. The third treatment = adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$. Fourth treatment = adding 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$. The fifth treatment = adding 2 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$.

The experiment included a study of the following traits: average live body weight, weight gain, feed consumption, food conversion ratio, and productivity index. The averages of these traits were estimated for each week of the experiment, which amounted to five weeks. A completely randomized design was used. To study the effect of different treatments on the studied traits, the differences between the means were compared using Duncan's polynomial test (15), and it used the ready-made statistical program (16) to analyze the data. The roots of the maca plant were purchased from the Al-Bustan Herbal Company in Kirkuk province (Figure 1).

**Table 1.** Percentage of feed materials and chemical composition included in the formation of the starter, growth, and final diet used in the experiment composition

| Feed ingredients | Diet types | | |
|---|---|---|---|
| | **Starter 1-10 day** | **Growth 11-21 day** | **Final 22-35 day** |
| yellow corn | 52.8 | 58.65 | 62.4 |
| wheat | 10 | 10 | 10 |
| protein concentrate* | 5 | 5 | 5 |
| Soybean meal 48% | 29.8 | 24 | 20.5 |
| Sun flower oil | 0.3 | 0.3 | 0.3 |
| Di-Calcium Phosphate | 0.5 | 0.35 | 0.2 |
| limestone | 1.14 | 1.21 | 1.22 |
| methionine | 0.17 | 0.17 | 0.13 |
| Lysine | 0.19 | 0.22 | 0.15 |
| Food salt | 0.1 | 0.1 | 0.1 |
| Total | 100 | 100 | 100 |
| **The calculated chemical analysis **** | | | |
| Represented energy (kilo calories/kg of feed) | 2940 | 2995 | 3035 |
| Crude protein (%) | 21.94 | 19.66 | 18.29 |
| Methionine + Cysteine (%) | 1.03 | 0.97 | 0.9 |
| Lysine (%) | 1.39 | 1.26 | 1.11 |
| Calcium (%) | 0.9 | 0.88 | 0.83 |
| Available phosphorous (%) | 0.44 | 0.41 | 0.38 |
| Crude fiber (%) | 2.73 | 2.64 | 2.58 |

*The protein concentrate used is animal produced by a Dutch company (imported) Brocon contains 40% raw protein, 2,017 kilocalories/kg protein-energy represented by 5% crude fat, 2.20% crude fiber, 5% calcium, 4.68% phosphorous, 3.85% lysine, 4.12% methionine, 4.12% methionine + cysteine, 0.42% tryptophan, 1.70% threonine. It contains a mixture of rare vitamins and minerals that provide the bird's need for these elements .The soybean meal used is from an Argentine source; the percentage of crude protein is 48%, and 2,440 kcal/kg is representative energy.** According to the chemical composition based on the NRC (1994).

**Figure 1.** The maca root used in the experiment

## 3. Results and Discussion

The average live body weights (g) ± standard error of the experimental treatments, where the results of the statistical analysis of the effect of adding different levels of maca roots to the diet on the average live body weight of broilers exposed to oxidative stress for the weeks of the experiment (amounted to 5 weeks), indicates that there are no significant differences among all treatments in the first week of the experiment (Table 2). As for the second, third, fourth, and fifth weeks of the experiment, a significant improvement ($P \leq 0.05$) for the birds of the first, third, fourth, and fifth treatment compared with the birds of the second treatment was observed.

Table 3 displays the results of the statistical analysis of the effect of adding different levels of maca roots to the diet on the average weight gain of broilers exposed to oxidative stress for the weeks of the experiment (totaling 5 weeks), indicating that there were no significant differences between all treatments during the first week of the experiment. In the second week of the experiment, the first, third, fourth, and fifth treatments were significantly improved ($P \leq 0.05$) compared to the second treatment, which showed the least weight gain. While in the third week, it was observed that the first, third, and fifth treatments were significantly improved ($P \leq 0.05$) in the average of weight gain compared to the second treatment, which recorded the least weight gain, followed by the fourth treatment, which did not differ significantly from the rest of the experimental treatments. In the fourth week, it is noticeable that the first, third, fourth, and fifth treatments were significantly superior ($P \leq 0.05$) over the second treatment, which showed the most negligible weight gain. While in the fifth week of the experiment, the first and fourth treatments indicated the highest weight gain and amounted to 711.89 and 745.67g, respectively and with a significant difference ($P \leq 0.05$) from the second treatment and the third treatment, which indicated a weight gain of 680.92 and 656.83g respectively. In contrast, there were no significant differences between the fifth treatment and the rest of the experiment's treatments. As for the total weight gain, it was shown that the birds of the first, third, fourth, and fifth treatments showed the highest total weight gain and amounted to 2326.21, 2278.00, 2250.35, and 2338.67 g, respectively, and with a significant difference ($P \leq 0.05$) on the birds of the second treatment, which displayed the lowest total weight gain and amounted to 2147.14 g.

**Table 2.** Effect of adding different levels of maca root to the diet on average live body weight (g) of broilers exposed to oxidative stress

| Treatments | Weeks of experiment | | | | |
|---|---|---|---|---|---|
| | **First week** | **Second week** | **Third week** | **Fourth week** | **Fifth week** |
| First treatment | 3.60±184.00 | 6.66±480.21[a] | 30.11±946.33[a] | 52.62±1627.00[a] | 56.33±2372.67[a] |
| Second treatment | 3.81±180.31 | 3.11±428.43[b] | 6.66±863.13[b] | 28.32±1500.22[b] | 11.21±2181.14[b] |
| Third treatment | 3.17±188.23 | 4.48±477.15[a] | 7.62±949.81[a] | 7.31±1627.52[a] | 34.91±2284.35[a] |
| Fourth treatment | 1.33±185.41 | 7.45±473.00[a] | 19.46±923.65[a] | 22.16±1600.11[a] | 29.71±2312.00[a] |
| Fifth treatment | 3.92±187.33 | 6.87±489.27[a] | 11.72±976.52[a] | 20.80±1659.08[a] | 47.79±2360.21[a] |
| Significance level | NS | * | * | * | * |

* The averages carrying different letters within the same column indicate differences at the level of significance ($P \leq 0.05$). NS: Not significant. The first treatment = control treatment (basic diet + drinking water free of $H_2O_2$); the second treatment = standard diet and water added to it $H_2O_2$ at a concentration of 0.5%; the third treatment = (adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); the fourth treatment = (adding 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); and the fifth treatment = (adding 2 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$).

**Table 3.** Effect of adding different levels of maca root to the diet on the average weight gain (g) of broilers exposed to oxidative stress (mean ± standard error)

| Treatments | Weeks of experiment | | | | | Total weight gain |
|---|---|---|---|---|---|---|
| | First week | Second week | Third week | Fourth week | Fifth week | |
| First treatment | 3.60±150.00 | 6.64±296.21[a] | 9.57±466.12[a] | 25.33±680.67[a] | 19.96±745.67[a] | 38.57±2338.67[a] |
| Second treatment | 3.71±146.31 | 6.35±248.12[b] | 3.83±434.70[b] | 18.78±637.09[b] | 12.34±680.92[b] | 11.21±2147.14[b] |
| Third treatment | 5.17±154.23 | 14.64±288.92[a] | 15.69±472.66[a] | 9.52±677.71[a] | 22.21±656.83[b] | 39.91±2250.35[a] |
| Fourth treatment | 4.33±151.41 | 8.19±287.59[a] | 24.86±450.65[ab] | 9.17±676.46[a] | 9.91±711.89[a] | 29.71±2278.00[a] |
| Fifth treatment | 3.92±153.33 | 7.31±301.94[a] | 9.66±487.25[a] | 10.80±682.56[a] | 25.59±701.13[ab] | 47.79±2326.21[a] |
| Significance level | NS | * | * | * | * | * |

* The averages carrying different letters within the same column indicate differences at the level of significance (*P*≤0.05). NS: Not significant. The first treatment = control treatment (basic diet + drinking water free of $H_2O_2$); the second treatment = standard diet and water added to it $H_2O_2$ at a concentration of 0.5%; the third treatment = (adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); the fourth treatment = (adding 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); and the fifth treatment = (adding 2 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$).

Table 4 shows the results of the statistical analysis of the effect of adding different levels of maca roots to the diet on the weekly feed consumption average of broilers exposed to oxidative stress for the weeks of the experiment, which amounted to 5 weeks, indicating that there were no significant differences between all treatments in the first and second weeks of the experiment. In the third week, we noticed that the third treatment recorded the highest average of feed consumption and amounted to 650.45g, with a significant difference (*P≤0.05*) from the first, second and fourth treatments, which revealed the lowest average of feed consumption and amounted to 621.33, 618.12, and 621.65g, respectively. As for the fifth treatment, there were no significant differences between it and the rest of the experimental treatments, while in the fourth and fifth week and the total feed consumption, there were no significant differences between all the experimental treatments.

Table 5 shows the results of the statistical analysis of the effect of adding different levels of maca roots to the diet on the feed conversion ratio of broilers exposed to oxidative stress for the weeks of the experiment, which amounted to 5 weeks, indicating that there were no significant differences between all the experimental treatments. As for the cumulative feed conversion ratio, it was observed that the birds of the first, fourth, and the fifth treatments had the best cumulative feed conversion ratio, and it amounted to 1.440, 1.447, and 1.442 gm of feed/g of weight gain/bird with a significant difference (*P*≤0.05) than the second treatment, which recorded a cumulative food conversion ratio of 1.546 gm of feed/g of weight gain/bird.

**Table 4.** Effect of adding different levels of maca root to the diet on the average feed consumption (g) of broilers exposed to oxidative stress (mean ± standard error)

| Treatments | Weeks of experiment | | | | | Total feed consumption |
|---|---|---|---|---|---|---|
| | First week | Second week | Third week | Fourth week | Fifth week | |
| First treatment | 2.18±190.31 | 34.37±409.67 | 6.17±621.33[b] | 33.65±964.00 | 29.20±1188.55 | 35.43±3373.86 |
| Second treatment | 6.22±188.23 | 37.50±383.00 | 10.72±618.12[b] | 23.21±926.54 | 38.82±1205.41 | 32.25±3321.30 |
| Third treatment | 3.38±185.16 | 31.43±431.23 | 11.09±650.45[a] | 25.20±935.42 | 48.60±1142.00 | 31.56±3344.26 |
| Fourth treatment | 2.02±189.42 | 32.17±377.28 | 9.63±621.65[b] | 34.22±931.67 | 25.21±1178.23 | 28.02±3298.25 |
| Fifth treatment | 2.90±186.12 | 25.65±416.17 | 8.28±635.34[ab] | 28.66±917.09 | 37.10±1195.65 | 33.64±3350.37 |
| Significance level | NS | NS | * | NS | NS | NS |

* The averages carrying different letters within the same column indicate differences at the level of significance (*P*≤0.05). NS: Not significant. The first treatment = control treatment (basic diet + drinking water free of $H_2O_2$); the second treatment = standard diet and water added to it $H_2O_2$ at a concentration of 0.5%; the third treatment = (adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); the fourth treatment = (adding 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); and the fifth treatment = (adding 2 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$).

**Table 5.** Effect of adding different levels of maca root to the diet on the feed conversion factor (gm of feed/g of weight gain/bird) for broilers exposed to oxidative stress (mean ± standard error)

| Treatments | Weeks of experiment | | | | | Cumulative feed conversion ratio |
|---|---|---|---|---|---|---|
| | First week | Second week | Third week | Fourth week | Fifth week | |
| First treatment | 0.027±1.268 | 0.161±1.383 | 0.065±1.332 | 0.037±1.416 | 0.084±1.593 | 0.020±1.442$^{b}$ |
| Second treatment | 0.033±1.286 | 0.192±1.543 | 0.020±1.421 | 0.046±1.454 | 0.028±1.770 | 0.017±1.546$^{a}$ |
| Third treatment | 0.049±1.200 | 0.194±1.492 | 0.026±1.376 | 0.044±1.380 | 0.045±1.738 | 0.042 ±1.486$^{ab}$ |
| Fourth treatment | 0.036±1.251 | 0.151±1.311 | 0.035±1.379 | 0.034±1.377 | 0.025±1.655 | 0.018±1.447$^{b}$ |
| Fifth treatment | 0.038±1.213 | 0.080±1.378 | 0.020±1.303 | 0.015±1.343 | 0.070 ± 1.705 | 0.025±1.440$^{b}$ |
| Significance level | NS | NS | NS | NS | NS | * |

* The averages carrying different letters within the same column indicate differences at the level of significance ($P \leq 0.05$). NS: Not significant. The first treatment = control treatment (basic diet + drinking water free of $H_2O_2$); the second treatment = standard diet and water added to it $H_2O_2$ at a concentration of 0.5%; the third treatment = (adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); the fourth treatment = (adding 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); and the fifth treatment = (adding 2 g of maca roots / kg of the basic diet + drinking water containing 0.5% $H_2O_2$).

Figure 2 indicates the effect of adding different levels of maca root to the diet on the production index of broilers exposed to oxidative stress for five weeks. Where the first, fourth, and fifth treatments recorded the highest productivity index and reached 470.11, 456.51, and 468.29, with a significant difference ($P \leq 0.05$), as compared to the second treatment, which showed the lowest productivity index and amounted to 403.09. In contrast, there were no significant differences between the third treatment and the rest of the experimental treatments.

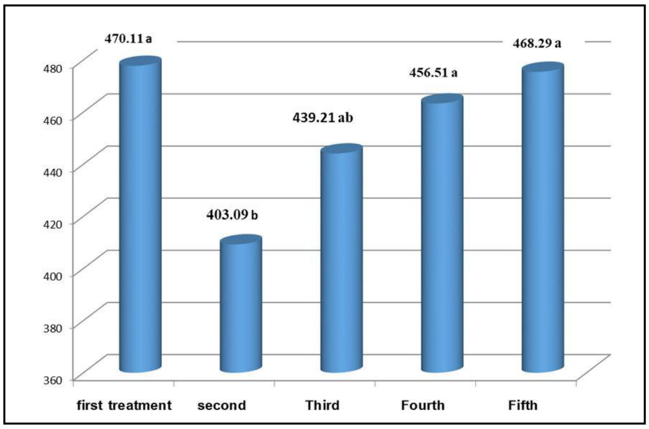


**Figure 2.** Effect of adding different levels of maca root to the diet on the production index of broilers exposed to oxidative stress

* The averages carrying different letters within the same column indicate differences at the level of significance ($P \leq 0.05$). The first treatment = control treatment (basic diet + $H_2O_2$ free drinking water); the second treatment = a standard diet and water added to it $H_2O_2$ at a concentration of 0.5%; the third treatment = (adding 1 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$); the fourth treatment = (add 1.5 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$). The fifth treatment = (adding 2 g of maca roots/kg of the basic diet + drinking water containing 0.5% $H_2O_2$).

The significant improvement in the average live body weight in the treatments of maca roots (third, fourth, and fifth) compared to the second treatment may be due to the role of the active substances found in maca roots, including glucosinolates, isothiocyanates, and quercetin which contain antioxidant properties. It works to remove oxygen or hydroxyl free radicals and stop the oxidative chain reaction (17, 18). Furthermore, maca roots contain fatty and amino acids and essential mineral elements, which are necessary for building and structuring the cell walls of the body's tissues and muscle cells (19). All of these roles can lead to an increase in the live body weight of broilers. As shown by the results in table 2, the significant decrease occurred in the second treatment without maca roots addition, which is due to the reduction in body weight is the result of $H_2O_2$ (hydrogen peroxide) addition, which works to increase the formation of free radicals, whose continuous interactions inside the body lead to the oxidation of lipids in the plasma membrane of cells, causing tissue damage and destruction (20). This may be responsible for reduction in the birds' weight. Which is an important indicator that indicates the amount of benefit from the feed and converts it into a live weight for broilers; any decrease in this value is evidence of an improvement in the food conversion ratio compared to the second treatment. This may be due to the presence of active compounds in maca roots that maintain the health of the digestive system and keep it healthy. It was found that plants and herbs used as animal feed additives increase the secretions of the digestive system and maintain its health because they contain biologically active ingredients. The most important of which are antioxidants and antimicrobials, which improve growth average and weight gain, helping to achieve the maximum benefit from the consumed feed and thus improving the feed conversion ratio (21). As for the significant improvement ($P \leq 0.05$) in live body weight and total weight gain, as well as the cumulative food conversion ratio for the first treatment (control) compared to the second treatment. It may be due to the excellent quality of the chicks and feed, the good management of the hall well during the experiment, and lack of exposure to any kind of stress during the experiment period, which was reflected in its productive performance. This improvement in the traits of productive performance is all positively reflected in the values of the production index, which is one of the crucial indicators in evaluating the productive performance of broilers. This is attributed to a high value in the maca root adding treatments and the first treatment due to the high average of live body weight and vital percentage, thus improving the food conversion ratio in these treatments. As the productivity index scale is directly proportional to the average live body weight and vital percentage.

## Authors' Contribution

Study concept and design: L. H. M.
Acquisition of data: L. H. M.
Analysis and interpretation of data: N. A. A.
Drafting of the manuscript: N. A. A.
Critical revision of the manuscript for important intellectual content: N. A. A.
Statistical analysis: L. H. M.
Administrative, technical, and material support: L. H. M.

## Ethics

The study protocol was approved by the ethics board of the Al-Qasim Green University, Al Qasim, Iraq.

## Conflict of Interest

The authors declare that they have no conflict of interest.

## References

1. Al-Awadi DHY, Al-Nadawi NA-LA. Effect of adding different levels of lemon grass leaves Cymbopogon citratus to the diet and its extract in drinking water on the quality characteristics of the carcass to broiler Chickens (Ross 308). J Genet Environ Resour Conserv. 2021;9(1):86-9.
2. Bartošikova L, Nečas J, Suchý V, Kubinova R, Vesela D, Beneš L, et al. Antioxidative effects of morine in ischemia-reperfusion of kidneys in the laboratory rat. Acta Vet Brno. 2003;72(1):87-94.
3. Prakash S, Joshi Y. Assessment of micronutrient antioxidants, total antioxidant capacity and lipid peroxidation levels in liver cirrhosis. Asia Pac J Clin Nutr. 2004;13.
4. Salami SA, Majoka MA, Saha S, Garber A, Gabarrou J-F. Efficacy of dietary antioxidants on broiler oxidative stress, performance and meat quality: science and market. Avian Biol Res. 2015;8(2):65-78.
5. McDonald P. Animal nutrition: Pearson Education India; 2002.

6. Campos D, Chirinos R, Barreto O, Noratto G, Pedreschi R. Optimized methodology for the simultaneous extraction of glucosinolates, phenolic compounds and antioxidant capacity from maca (Lepidium meyenii). Ind Crops Prod. 2013;49:747-54.
7. Ali NA-L, Al-Shuhaib MBS. Highly effective dietary inclusion of laurel (Laurus nobilis) leaves on productive traits of broiler chickens. Acta Sci Anim Sci. 2021;43.
8. Wang S, Zhu F. Chemical composition and health effects of maca (Lepidium meyenii). Food Chem. 2019;288:422-43.
9. Turgud FK, Narinç D. Influences of Dietary Supplementation with Maca (Lepidium meyenii) on Performance, Parameters of Growth Curve and Carcass Characteristics in Japanese Quail. Animals. 2022;12(3):318.
10. Qiu C, Zhu T, Lan L, Zeng Q, Du Z. Analysis of maceaene and macamide contents of petroleum ether extract of black, yellow, and purple Lepidium meyenii (maca) and their antioxidant effect on diabetes mellitus rat model. Braz Arch Biol Technol. 2016;59.
11. Gonzales GF, Villaorduña L, Gasco M, Rubio J, Gonzales C. Maca (Lepidium meyenii Walp), a review of its biological properties. Rev Peru Med Exp Salud Publica. 2014;31(1):100-10.
12. Del Prete C, Tafuri S, Ciani F, Pasolini M, Ciotola F, Albarella S, et al. Influences of dietary supplementation with Lepidium meyenii (Maca) on stallion sperm production and on preservation of sperm quality during storage at 5 C. Andrology. 2018;6(2):351-61.
13. Ali NA-L, Al-Nasrawi MA, Al-Kassie GA. Investigation on the effect of adding diverse concentrations of aqueous extract of oregano leaves (origanum vulgare) on physiological and immunological behaviors of broiler. Biochem Cell Arch. 2021;12(1): 2657-661.
14. Korkmaz S, Eseceli H, Omurtag Korkmaz I, Bilal T. Effect of Maca (Lepidium meyenii) powder dietary supplementation on performance, egg quality, yolk cholesterol, serum parameters and antioxidant status of laying hens in the post-peak period. Eur Poult Sci. 2016;80:1-9.
15. Duncan DB. Multiple range and multiple F tests. biometrics. 1955 Mar 1;11(1):1-42.
16. Cary N. Statistical analysis system, User's guide. Statistical. Version 9. SAS Inst Inc USA. 2012.
17. Fahey JW, Zalcmann AT, Talalay P. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. Phytochemistry. 2001;56(1):5-51.
18. Elliott M, Chithan K. The impact of plant flavonoids on mammalian biology: implications for immunity, inflammation and cancer. The flavonoids: Routledge; 2017. p. 619-52.
19. Chen L, Li J, Fan L. The nutritional composition of maca in hypocotyls (Lepidium meyenii Walp.) cultivated in different regions of China. J Food Qual. 2017;2017.
20. Combs G. Clinical implications of selenium and vitamin E in poultry nutrition. Vet Clin Nutr. 1994;1(3):133-40.
21. Wallace R, Oleszek W, Franz C, Hahn I, Baser K, Mathe A, et al. Dietary plant bioactives for poultry health and productivity. Br Poult Sci. 2010;51(4):461-87.