Poultry Studies, 19(1), 19-24
http://doi.org/10.34233/jpr.1138469

PROOF
RESEARCH PAPER

POULTRY STUDIES

Effects of *in Ovo* Application of Resveratrol on Hatchability, Hatching Time, Yolk Sac Weight and Chick Performance in Quail

Mohammed Kamil Kattami Alsadoon[1], Ali Aygün [1,*]

[1] Selçuk University, Agriculture Faculty, Department of Animal Science, 42250, Konya, Turkey

Article History
Received 25 Apr 2022
Accepted 21 June 2022
First Online 30 June 2022

***Corresponding Author**
Tel: +903322232905
E-mail: aaygun@selcuk.edu.tr

Keywords
Resveratrol
Hatchability
Yolk sac
Performance
Hatching time

Abstract

The purpose of this study was to investigate the effects of *in ovo* resveratrol in hatching quail eggs on hatching traits, organ weights and chick performance. A total of 640 hatching quail eggs were used in the study. The eggs were randomly distributed into four groups as non-injected group (PC; Positive control), 0.2 ml saline (NC; Negative control), 0.2 ml solution containing 1 nmol of resveratrol (R1) and 0.2 ml solution containing 4 nmol of resveratrol (R4). *In ovo* injection was performed on the 14th day of incubation. Hatchability of set eggs (HSE) and hatchability of fertile eggs (HFE), embryonic mortality (EM), chick hatching time, yolk sac weight (YSW), and chick performance characteristics were investigated. The effects of *in ovo* resveratrol administration on the HSE were insignificant. HFE decreased significantly with *in ovo* resveratrol treatment ($P<0.05$). All injected groups were adversely affected in terms of embryonic deaths ($P<0.05$). The effect of *in ovo* resveratrol application on chick hatch weight, and YSW (g, %), chick performance was insignificant. It was observed that *in ovo* resveratrol treatment had no significant effect on the hatching time, except at 408 h of incubation. As a result, *in ovo* resveratrol application had a negative effect on hatchability and EM, but did not have affected the hatching time, yolk sac weight and chick performance.

Introduction

In *ovo* application is a method to apply exogenous substances into the amnion during embryo development in order to promote positive effects on egg hatching, post-hatching performance and immune response (Uni and Ferket 2004). This method was first used to administer a marek vaccine (Sharma and Burmester 1982).

Researchers have used ascorbic acid, carbohydrates, amino acids, vitamin-minerals, hormones and bee products (Kocamis et al., 1999; Salmanzadeh et al., 2012; Coşkun et al., 2014a; Coşkun et al., 2014b; Moghaddam et al., 2014; Sgavioli et al., 2015; Yair et al., 2015; Coskun et al., 2017; Maman et al., 2019; Alizadeh et al., 2022) in the in ovo method in recent years. Resveratrol is a polyphenolic phytoalecsin synthesized by plants in response to environmental stress or pytopathogene attacks. Phytoalectiles are chemicals that are synthesized to protect plants against pathogenic microorganisms (Langcake and Pryce 1977). Resveratrol protects body cells against naturally occurring free radicals (Lin and Tsai 1999). It has been stated that resveratrol has antioxidant, antiplatelet, cardioprotective, vascular relaxant, anticancerogen and anti-inflammatory effects (Soleas et al., 1997; Tan et al., 2015).

El-Fakhrany et al., (2021) stated that in ovo resveratrol application to broiler eggs has a positive effect on kidney and liver functions, immune function except chick performance. Resveratrol is mostly given in the form of additions to feed in poultry (Sahin et al., 2010; Sridhar et al., 2015; Mohebodini et al., 2019; Zhang et al., 2020; Wang et al., 2021), and the

application of in ovo is limited (Tan *et al.,* 2015; El-Fakhrany *et al.,* 2021).

The aim of this study was to investigate the effect of *in ovo* injection of resveratrol on hatching results, yolk sac weight, hatching time and chick performance.

Materials and Methods

A total of 640 hatching quail eggs were used in the study. Eggs were randomly allocated to four treatment group with 160 eggs per treatment with four replicates of 40 eggs each. Experimental groups were arranged as the group eggs not injected with solution (Positive control; PC), the second group eggs were injected with saline (Negative control; NC), the third group eggs were injected with 1nmol resveratrol (R1) and the fourth group eggs was injected with 4 nmol resveratrol (R4) (Extrasynthese, France, Purity (HPLC) ≥99%). The application doses were diluted to be every 0.20 mL. On the 14th day of incubation, the blunt end of the eggs was opened with the device. Then, the prepared doses (0.20 mL) were injected into the amniotic fluid with a needle (26-gauge syringe). After the application, the eggs were transferred to the hatching unit after the hole was closed with wax.

Chick hatching were recorded every 3 h from the 390th h of incubation until the time when chick hatching was completed. The chicks were transferred to the cages for their growth performance after they completed hatching, unhatched eggs were opened, and dead embryos were determined according to guidelines of (Aygun et al., 2012). The following characteristics were calculated from these data.

Fertility (%) = Fertile eggs / total eggs * 100
HFS (%)= Hatched chicks/ fertile eggs * 100
HSE (%)=Hatched chicks/total eggs * 100

After hatching, yolk sac weight was determined in 5 chicks from each group. For this purpose, the chicks were weighed and killed, the yolk sac was removed and weighed to the nearest 0.01 g. The yolk sac weight was divided by the body weight and expressed as %.

In order to measure chick performance, 10 chicks (40 chicks/group) randomly selected from each subgroup were individually weighed, wing banded and placed in brooding cages. Chicks were fed with grower diet (24% CP and 2,900 kcal ME/kg) during the 10 d of rearing period. The room temperature is adjusted to be 33-35℃ and continuous light is preferred as photoperiod until the end of the rearing period. The chicks were individually weighed at the end of the 10 d rearing period and the relative growth was calculated using these data (Tona et al., 2003). Chick deaths were recorded daily.

Relative Growth (RG) = [Body weight of d 10 (g)-Initial body weight (g)] / Initial body weight (g) *100

The data of hatching traits, hatch time, yolk sac weight, and chick performance characteristics were analyzed using variance analysis, and performed by

Tukey's multiple range test for comparison mean values of treatment groups. Statistically significant level (P) was 0.05.

Results and Discussion

The HSE, HFE and EM of the experiment are summarized in Table 1. No significant differences were found among treatments group for HSE. In terms of HFE, the PC group (84.13%) was higher than the NC (62.26%), R1 (64.05%) and R4 (57.90 %) treatment groups. However, no statistically significant difference was observed among the NC, R1 and R4 groups in terms of HF. There are studies showing that in ovo injection of different substances has positive or negative effects on hatchability. Hatchability were adversely affected by in ovo injection propolis (Aygun 2016), amino acids (Groff-Urayama et al., 2019; Nazem et al., 2019), organic trace minerals (Oliveira et al., 2015), and vitamin D_3 (Maman et al., 2019).

On the other hand, hatchability was improved by in ovo injection with histidine (Xu et al., 2019), naringin (Ranjbar et al., 2019), vitamin C (Zhu et al., 2020), and carbohydrates (Dong et al., 2013)

Beck et al., (2019), Khaligh et al., (2018); Ncho et al., (2021), and Coşkun et al., (2014a) stated that hatchability was not affected when eggs were injected with probiotics, quercetin, gaba and pollen, respectively. Giving different substances into egg with in ovo application can create nutrient imbalances in the egg and this can cause embryo death.

Embryonic mortality at 1-9 d of incubation in the PC (10.77%) and R4 (9.24%) groups were higher than in the NC (3.16%) and R1 (3.16%) groups ($P<0.05$). Embryonic mortality at 10-16 d of incubation were the lowest in the PC group (5.11%) ($P<0.05$). There were no significant differences among the groups for embryonic mortality on days 17-18 of incubation. The use of resveratrol may be toxic for the embryo development. In ovo administration may cause an allergic reaction due to changes in the amniotic fluid and cause embryos to die (Salmanzadeh et al., 2012).

The effect of *in ovo* resveratrol application on spread of hatch is given in Figure 1. The first chick hatching times were observed in the PC, NC, R1 and R4 groups at 408, 402, 402 and 405 hours, respectively. Chick hatching was completed in all groups at 438 h of incubation. R1 group (22.49%) had significantly higher hatching percentage than that of PC group (0.96%) at 408 h of incubation, but no significant differences were observed among NC (14.89%), R1 (22.49%), and R4 (5.24%) group at 408 h of incubation. There were no significant differences among groups at other hatching times.

Table 1. Effects of *in ovo* resveratrol on HSE, HFE and EM (mean ± SE)

Group	Fertility	HSE	HFE	EM (% of fertile eggs)		
				1-9 d	10-16 d	17-18 d
PC	75.81± 3.79	63.71 ± 2.75	84.13± 0.91^{a}	10.77±1.15^{a}	5.11±1.07^{b}	0.00±0.00
NC	81.71±1.45	50.10± 3.49	62.26± 3.29^{b}	3.16±1.24^{b}	31.36±2.90^{a}	3.23±0.18
R1	84.65±1.64	54.11± 2.84	64.05 ±3.88^{b}	3.16±1.24^{b}	25.93±5.93^{a}	0.78±0.78
R4	82.29±1.75	47.41± 5.85	57.90±7.82^{b}	9.24±2.45^{ab}	33.74±6.36^{a}	2.21±2.20
P-value	0.10	0.06	0.00	0.04	0.00	0.37

$^{a-b}$ Different letters in the same column indicate significant differences (P<0.05)
PC: Positive control, no injection; NC: Negative control, only saline injection; R1: 1nmol resveratrol injection; R4: 4 nmol resveratrol injection, SE: Standard error

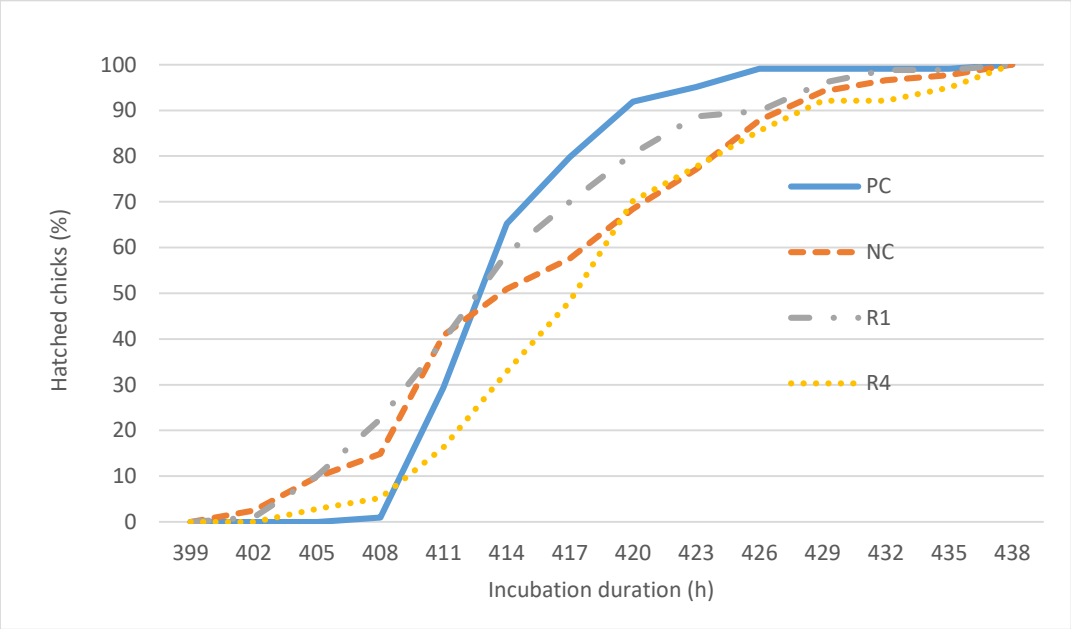

Figure 1. Effects of *in ovo* resveratrol injection on spread of hatch

PC: Positive control, no injection; NC: Negative control, only saline injection; R1: 1nmol resveratrol injection; R4: 4 nmol resveratrol injection

It can be stated that the narrower the time between the first and last chicks hatching, the higher the homogeneity in chicks. The longer the chicks stay in the incubator, the delayed access to feed, dehydration, and reduce post-hatch performance (Gonzales *et al.,* 2003; Careghi *et al.,* 2005; Powell *et al.,* 2016; Özlü *et al.,* 2018).

Chick body weight at hatch, YSW (g, %) of treatments groups are summarized in Table 2. No statistical significant differences were observed among groups for chick body weight at hatch, YSW (g, %). Chick hatching weight and egg yolk weight were not affected by in ovo resveratrol application. This result is consistent with the studies of Abdulqader et al., (2018); Senturk et al., (2018); Maman et al., (2019); Nazem et al., (2019) that *in ovo* probiotic, Vitamin D_3, amino acids, and manganese injections do not affect the chick hatching weight, respectively.

Conversely, Tangara et al., (2010) chick weight was significantly increased by *in ovo* injection of carbohydrates and arginine relative to control treatment in ducks. Ncho et al., (2021) stated that in ovo application with 5% GABA had a higher hatching weight compared with control group.

No significant differences were found among treatments group for yolk sac weight (g, %). There are similar studies showing that the injection of *in ovo* substances has no effect on chick hatching weight (Abdulqader *et al.,* 2018; Groff-Urayama *et al.,* 2019; Maman *et al.,* 2019). On the other hand, Zamani *et al.,* (2018) reported *in ovo* carbohydrates injection significantly decreased the yolk sac residue compared with control group (P<0.05). The weight of the yolk sac in poultry varies between 10% and 25% of the hatching body weight. (Jamroz et al., 2004; Abdulqader et al., 2018).

Table 2. Effects of *in ovo* resveratrol on chick hatching weight and yolk sac weight (mean ± SE)

Group	Chick hatching weight, g	Yolk sac weight, g	Yolk sac weight (%)
PC	8.25 ± 0.50	0.79 ± 0.12	9.48 ± 1.02
NC	8.34 ± 0.64	1.05 ± 0.14	12.46 ± 1.09
R1	8.58 ± 0.18	1.13 ± 0.25	13.20 ± 2.10
R4	8.79 ± 0.54	1.41 ± 0.25	16.30 ± 3.41
P-value	0.81	0.14	0.16

PC: Positive control, no injection; NC: Negative control, only saline injection; R1: 1nmol resveratrol injection; R4: 4 nmol resveratrol injection, SE: Standard error

Table 3. Effects of *in ovo* resveratrol on chick body weight (1 d and 10 d) and relative growth (mean ± SE)

Group	Body weight, g, (1 d)	Body weight, g, (10 d)	Relative growth
PC	8.35± 0.15	44.73± 0.93	437.73± 9.90
NC	8.14± 0.14	42.76± 1.17	430.11± 1.96
R1	8.38± 0.12	44.37± 0.88	430.26± 8.83
R4	8.27± 0.190	44.07± 1.46	433.98± 15.21
P-value	0.69	0.59	0.97

PC: Positive control, no injection; NC: Negative control, only saline injection; R1: 1nmol resveratrol injection; R4: 4 nmol resveratrol injection, SE: Standard error

Egg yolk sac is very rich in nutrients necessary for the embryonic development and for feeding in the early post-hatching period (Noy and Sklan 1998; Jamroz *et al.,* 2004)

In ovo resveratrol administration on chick body weight at d 1, body weight at d 10, and relative growth are presented Table 3. It has been previously stated by some researchers that in ovo substances injection does not have a significant effect on body weight gain (Aygun 2016; Khaligh et al., 2018; Zhu et al., 2020; Ncho et al., 2021).

The results of our study are inconsistent with Hassan et al., (2021), which reported in ovo Nano Cu or Cu sulfate injection caused a significant increase in body weight at 35 days of age compared to the group. Similarly, Al-Daraji et al., (2012) reported that in ovo L-arginine injection presented higher weight gain than control groups ($P<0.05$).

Conclusions

According to our research results, *in ovo* resveratrol administration had a negative effect on hatchability and EM. However, it is seen that there is no negative effect on chick hatching weight, yolk sac weight, hatching time and post-hatch performance.

Highlights

- Resveratrol is applied as *in ovo* application into quail hatching eggs.
- In ovo resveratrol application negatively affected hatchability and embryonic mortality.
- In ovo resveratrol application has not had any effect on hatching time, yolk sac weight and chick performance.

Acknowledgments

This study was summarized from Mohammed Kamil Kattami ALSADOON's Master's Thesis and supported by Selçuk University (project number: 19201058).

References

Abdulqader, A. F., Aygün, A., Maman, A. H., Olgun, O. 2018. The effect of in-ovo injection of Lactobacilla Rhamnosus on hatching traits and growth parameters of quails. Selcuk Journal of Agriculture and Food Science, *32*(2): 174-178.

Al-Daraji, H., Al-Mashadani, A., Al-Mashadani, W., Al-Hassani, A., Mirza, H. 2012. Effect of in ovo injection with L-arginine on productive and physiological traits of Japanese quail. South African Journal of Animal Science, *42*(2): 139-145.

Alizadeh, M., Astill, J., Alqazlan, N., Shojadoost, B., Taha-Abdelaziz, K., Bavananthasivam, J., Doost, J. S., Sedeghiisfahani, N., Sharif, S. 2022. *In ovo* co-administration of vitamins (A and D) and probiotic lactobacilli modulates immune responses in broiler chickens. Poultry science, *101*: 101717.

Aygun, A. 2016. The effects of in-ovo injection of propolis on egg hatchability and starter live performance of japanese quails. Brazilian Journal of Poultry Science, *18*(SPE2): 83-89.

Aygun, A., Sert, D., Copur, G. 2012. Effects of propolis on eggshell microbial activity, hatchability, and chick performance in Japanese quail (Coturnix coturnix japonica) eggs. Poultry science, *91*(4): 1018-1025.

Beck, C. N., McDaniel, C. D., Wamsley, K. G., Kiess, A. S. 2019. The potential for inoculating Lactobacillus animalis and Enterococcus faecium alone or in combination using commercial in ovo technology without negatively impacting hatch and post-hatch performance. Poultry science, *98*(12): 7050-7062.

Careghi, C., Tona, K., Onagbesan, O., Buyse, J., Decuypere, E., Bruggeman, V. 2005. The effects of the spread of hatch and interaction with delayed feed access after hatch on broiler performance until seven days of age. Poultry science, *84*(8): 1314-1320.

Coskun, I., Korkmaz, F., Altop, A., Cayan, H., Filik, G., Sahin, A., Samli, H. E. 2017. The effects of in ovo pollen extract injection on growth parameters, ileal histomorphology and caecal microflora in fasted broiler chicks. Indian Journal of Animal Research, *51*(6): 1033-1037.

Coşkun, I., Çayan, H., Yilmaz, Ö., Taskin, A., Tahtabicen, E., Samli, H. E. 2014a. Effects of in-ovo pollen extract injection to fertile broiler eggs on hatchability and subsequent chick weight. Turkish Journal of Agricultural and Natural Sciences, *1*(4): 485-489.

Coşkun, I., Erener, G., Şahin, A., Karadavut, U., Altop, A., Okur, A. A. 2014b. Impacts of in ovo feeding of DL-methionine on hatchability and chick weight. Turkish Journal of Agriculture-Food Science and Technology, *2*(1): 47-50.

Dong, X., Jiang, Y., Wang, M., Wang, Y., Zou, X. 2013. Effects of in ovo feeding of carbohydrates on hatchability, body weight, and energy status in domestic pigeons (Columba livia). Poultry science, *92*(8): 2118-2123.

El-Fakhrany, H. H., Ibrahim, Z. A., Ashour, E. A., Alagawany, M. 2021. Efficacy of in ovo delivered resveratrol (Trans 3, 4, 5-trihydroxystilbene) on growth, carcass weights, and blood metabolites of broiler chicks. Animal Biotechnology: 1-8.

Gonzales, E., Kondo, N., Saldanha, E., Loddy, M., Careghi, C., Decuypere, E. 2003. Performance and physiological parameters of broiler chickens subjected to fasting on the neonatal period. Poultry science, *82*(8): 1250-1256.

Groff-Urayama, P., Padilha, J., Einsfeld, S., Pertile, S., Gorges, M., Andrade, M., Domenico, A., MidoriMaeda, E., Takahashi, S., Plaizier, J. 2019. Performance, intestinal morphometry, and incubation parameters of broiler chickens submitted to in ovo feeding with different techniques and amino acids. Canadian Journal of Animal Science, *99*(4): 732-740.

Hassan, H. A., Arafat, A., Farroh, K., Bahnas, M., El-Wardany, I., Elnesr, S. S. 2021. Effect of in ovo copper injection on body weight, immune response, blood biochemistry and carcass traits of broiler chicks at 35 days of age. Animal Biotechnology: 1-8.

Jamroz, D., Wertelecki, T., Wiliczkiewicz, A., Orda, J., Skorupińska, J. 2004. Dynamics of yolk sac resorption and post-hatching development of the gastrointestinal tract in chickens, ducks and geese. Journal of animal physiology and animal nutrition, *88*(5-6): 239-250.

Khaligh, F., Hassanabadi, A., Nassiri-Moghaddam, H., Golian, A., Kalidari, G. A. 2018. Effects of in ovo injection of chrysin, quercetin and ascorbic acid on hatchability, somatic attributes, hepatic oxidative status and early post-hatch performance of broiler chicks. Journal of animal physiology and animal nutrition, *102*(1): e413-e420.

Kocamis, H., Yeni, Y., Kirkpatrick-Keller, D., Killefer, J. 1999. Postnatal growth of broilers in response to in ovo administration of chicken growth hormone. Poultry science, *78*(8): 1219-1226.

Langcake, P., Pryce, R. 1977. A new class of phytoalexins from grapevines. Experientia, *33*(2): 151-152.

Lin, J.-K., Tsai, S.-H. 1999. Chemoprevention of cancer and cardiovascular disease by resveratrol. Proceedings of the National Science Council, Republic of China. Part B, Life sciences, *23*(3): 99-106.

Maman, A. H., Aygün, A., Yildirim, İ., Alsadoon, M. K. K. 2019. Effects of In-Ovo Injection of D3 Vitamin on Hatchability and Supply Organ Weights in Quail Hatching Eggs. Journal of Bahri Dagdas Animal Research, *8*(1): 21-27.

Moghaddam, A., Borji, M., Komazani, D. 2014. Hatchability rate and embryonic growth of broiler chicks following in ovo injection royal jelly. British poultry science, *55*(3): 391-397.

Mohebodini, H., Jazi, V., Bakhshalinejad, R., Shabani, A., Ashayerizadeh, A. 2019. Effect of dietary resveratrol supplementation on growth performance, immune response, serum biochemical indices, cecal microflora, and intestinal morphology of broiler chickens challenged with *Escherichia coli*. Livestock Science, *229*: 13-21.

Nazem, M. N., Amiri, N., Tasharrofi, S. 2019. Effect of in ovo feeding of amino acids and dextrose solutions on hatchability, body weight, intestinal development and liver glycogen reserves in newborn chicks. Veterinary research forum, *10*(4): 323-331.

Ncho, C.-M., Goel, A., Jeong, C.-M., Youssouf, M., Choi, Y.-H. 2021. In Ovo Injection of GABA Can Help Body Weight Gain at Hatch, Increase Chick Weight to Egg Weight Ratio, and Improve Broiler Heat Resistance. Animals, *11*(5): 1364.

Noy, Y., Sklan, D. 1998. Yolk utilisation in the newly hatched poult. British poultry science, *39*(3): 446-451.

Oliveira, T., Bertechini, A., Bricka, R., Kim, E., Gerard, P., Peebles, E. 2015. Effects of in ovo injection of organic zinc, manganese, and copper on the hatchability and bone parameters of broiler hatchlings. Poultry science, *94*(10): 2488-2494.

Özlü, S., Shiranjang, R., Elibol, O., Brake, J. 2018. Effect of hatching time on yolk sac percentage and broiler live performance. Brazilian Journal of Poultry Science, *20*: 231-236.

Powell, D., Velleman, S., Cowieson, A., Singh, M., Muir, W. 2016. Influence of hatch time and access to feed on intramuscular adipose tissue deposition in broilers. Poultry science, *95*(6): 1449-1456.

Ranjbar, Z., Torki, M., Karimi Torshizi, A. A. 2019. In ovo injection of flavanone on bone quality characteristics, biochemical parameters and antioxidant enzyme status of blood in daily chicks. Journal of animal physiology and animal nutrition, *103*(5): 1418-1426.

Sahin, K., Akdemir, F., Orhan, C., Tuzcu, M., Hayirli, A., Sahin, N. 2010. Effects of dietary resveratrol supplementation on egg production and antioxidant status. Poultry science, *89*(6): 1190-1198.

Salmanzadeh, M., Ebrahimnezhad, Y., Shahryar, H. A., Beheshti, R. 2012. The effects of in ovo injection of glucose and magnesium in broiler breeder eggs on hatching traits, performance, carcass characteristics and blood parameters of broiler chickens. Arch. Geflugelkunde, *76*: 277-284.

Senturk, E. T., Aygun, A., Olgun, O., Yıldız, A. O. 2018. Effects of In-Ovo Injection of Manganese on Some Organ Weights and Lengths in Quail Hatching Eggs. Selcuk Journal of Agriculture and Food Sciences, *32*(3): 345-349.

Sgavioli, S., Matos Júnior, J., Borges, L., Praes, M., Morita, V., Zanirato, G., Garcia, R., Boleli, I. 2015. Effects of ascorbic acid injection in incubated eggs submitted to heat stress on incubation parameters and chick quality. Brazilian Journal of Poultry Science, *17*(2): 181-189.

Sharma, J., Burmester, B. 1982. Resistance of Marek's disease at hatching in chickens vaccinated as embryos with the turkey herpesvirus. Avian Diseases: 134-149.

Soleas, G. J., Diamandis, E. P., Goldberg, D. M. 1997. Wine as a biological fluid: history, production, and role in disease prevention. Journal of clinical laboratory analysis, *11*(5): 287-313.

Sridhar, M., Suganthi, R., Thammiaha, V. 2015. Effect of dietary resveratrol in ameliorating aflatoxin B1-induced changes in broiler birds. Journal of animal physiology and animal nutrition, *99*(6): 1094-1104.

Tan, R.-R., Zhang, S.-J., Tsoi, B., Huang, W.-S., Zhuang, X.-J., Chen, X.-Y., Yao, N., Mao, Z.-F., Tang, L.-P., Wang, Q. 2015. A natural product, resveratrol, protects against high-glucose-induced developmental damage in chicken embryo. Journal of Asian natural products research, *17*(5): 586-594.

Tangara, M., Chen, W., Xu, J., Huang, F., Peng, J. 2010. Effects of in ovo feeding of carbohydrates and arginine on hatchability, body weight, energy metabolism and perinatal growth in duck embryos and neonates. British poultry science, *51*(5): 602-608.

Tona, K., Bamelis, F., De Ketelaere, B., Bruggeman, V., Moraes, V., Buyse, J., Onagbesan, O., Decuypere, E. 2003. Effects of egg storage time on spread of hatch, chick quality, and chick juvenile growth. Poultry science, *82*(5): 736-741.

Uni, Z., Ferket, R. 2004. Methods for early nutrition and their potential. World's Poultry Science Journal, *60*(1): 101-111.

Wang, C., Zhao, F., Li, Z., Jin, X., Chen, X., Geng, Z., Hu, H., Zhang, C. 2021. Effects of Resveratrol on Growth Performance, Intestinal Development, and Antioxidant Status of Broilers under Heat Stress. Animals, *11*(5): 1427.

Xu, Q. Q., Zhang, X. Y., Zou, X. T., Dong, X. Y. 2019. Effects of in ovo injection of L-histidine on hatch performance and post-hatch development in domestic pigeons (Columba livia). Poultry science, *98*(8): 3194-3203.

Yair, R., Shahar, R., Uni, Z. 2015. In ovo feeding with minerals and vitamin D3 improves bone properties in hatchlings and mature broilers. Poultry science, *94*(11): 2695-2707.

Zamani, A., Shariatmadari, F., Rahimi, S., Karimi Torshizi, M. A. 2018. Effects of in ovo injection of carbohydrates, β-hydroxy-β-methylbutyrate, and vitamins on ostrich organ weight, bone characteristics, and small intestinal morphology. Canadian Journal of Animal Science, *99*(1): 116-122.

Zhang, F., Jin, C., Jiang, S., Wang, X., Yan, H., Tan, H., Gao, C. 2020. Dietary Supplementation with Pioglitazone Hydrochloride and Resveratrol Improves Meat Quality and Antioxidant Capacity of Broiler Chickens. Applied Sciences, *10*(7): 2452.

Zhu, Y., Li, S., Duan, Y., Ren, Z., Yang, X., Yang, X. 2020. Effects of in ovo feeding of vitamin C on post-hatch performance, immune status and DNA methylation-related gene expression in broiler chickens. British Journal of Nutrition, *124*(9): 903-911.