

IN OVO FEEDING OF CINNAMON EXTRACT IN BROILER CHICKENS

Izabela Helena Neradová, Lukáš Čumplík, Lenka Kudlová, Dana
Zálešáková, Ondřej Šťastník, Leoš Pavlata, Jakub Novotný

*Department of Animal Nutrition and Forage Production,
Faculty of AgriSciences, Mendel University in Brno, Zemědělská 1665/1 613 00
Brno, Czech Republic*

Corresponding email address: xnerado2@mendelu.cz

ABSTRACT

The study investigated the effect of *in ovo* application of cinnamon extract on the hatchability and performance parameters of broiler chickens. The primary objective was to evaluate the impacts of this early developmental programming on growth performance. Hatching eggs of the Ross 308 were divided into two groups: a control group (without application) and an experimental group supplemented with cinnamon extract. The cinnamon extract, prepared by hydroalcoholic extraction, was injected into the amnion on day 17.5 of incubation as a 0.2 mL solution, delivering a dose of 1.8 mg per egg. The subsequent 35 day feeding trial involved 144 male broiler chickens distributed into the two groups with 6 replicates each (12 birds per replicate). At the end of the fattening period, growth performance parameters (live body weight, carcass yield, and feed conversion ratio), were evaluated. The *in ovo* delivery of cinnamon extract did not significantly affect hatchability ($p > 0.05$) and showed no adverse effects on the growth performance of the broiler chickens ($p > 0.05$). These results demonstrate that the *in ovo* application of cinnamon extract is safe and does not impair growth performance, thereby providing a solid foundation for future research into chicken health status, digestive tract development, and immune system response.

Keywords: cinnamaldehyde; early developmental programming; growth performance; hatchability; phytogetic additives; poultry nutrition

INTRODUCTION

In recent years, the poultry sector has been actively transitioning toward minimizing antibiotic reliance. This pressure comes from rising antibiotic resistance and strict regulations, such as the EU ban on antibiotic growth promoters (Regulation (EC) No 1831/2003). Therefore, researchers are looking for safe, natural alternatives to maintain broiler growth and keep animals healthy. Phytogetic feed additives, such as plant extracts and essential oils, are excellent alternatives. They are popular because they can fight bacteria, reduce oxidative stress, and lower inflammation (Wang et al. 2024).

Using these plant additives with the *in ovo* (IO) method is a promising strategy to improve embryonic development. This method is based on early metabolic programming (Jha et al. 2019). It injects nutrients or bioactive compounds directly into the egg, usually on day 12 or days 17–18 of incubation (DOI). Researchers usually inject the solution into the air cell or the amnion (Das et al. 2021). This intervention stimulates the development of the gut and the immune system before the chicken hatches. As a result, newly hatched chickens have better vitality and a stronger physiological start for future growth (Ebeid et al. 2023).

Based on current knowledge, several phytoiotics show great potential for IO application. These include extracts from black cumin (*Nigella sativa*) (Oke et al. 2021; Oyelola et al. 2023), oregano (*Origanum vulgare*) (Niknafs et al. 2024; Elbaz et al. 2025), thyme (*Thymus vulgaris*), and clove (*Eugenia caryophyllata*) (El-Kholy et al. 2021).

Studies confirm that these extracts bring concrete physiological benefits. Specifically, Oke et al. (2021) observed improvements in both health status and performance parameters of heat-stressed chickens due to the antioxidant effects of black cumin. Similarly, thyme extract administered IO increases body weight (BW) both at hatch and at slaughter age compared to the control group, while improving the feed conversion ratio (FCR) (El-Kholy et al. 2021).

Essential oils (EOs) also fall under this category of promising additives, exhibiting a wide range of biological activities due to their complex mixtures of active compounds. Recently, Khaskheli et al. (2025) found that EOs from ylang-ylang, clary sage, bergamot, lemon myrtle, and black pepper increase the expression of genes related to gut barrier integrity, nutrient transport, and digestive enzyme activity. Meanwhile, EOs from ylang-ylang, turmeric, star anise, clary sage, and black pepper promote the expression of gut immunity markers.

Ceylon cinnamon (*Cinnamomum verum*) is especially interesting due to its strong antioxidant properties. Its main active component, cinnamaldehyde, increases the secretion of digestive enzymes and stabilizes the gut microbiota (Ali et al. 2021). This component works mainly through intestinal TRPA1 receptors. It influences ion channels and secretions, which ultimately improves the morphological development of the intestine (Manneck et al. 2021).

In ovo application is a sensitive intervention into the egg that can alter embryonic homeostasis, so verifying dosage safety for the embryo is a critical first step. Based on the documented antioxidant properties of cinnamon, this study hypothesizes that the IO injection of a hydroalcoholic extract (1.8 mg/egg) will enhance breast meat yield at the end of the 35-day fattening period without compromising other growth variables. Therefore, the primary objective of this study was to evaluate how IO cinnamon extract delivery on 17.5 DOI affects the hatchability of Ross 308 eggs and the subsequent growth performance (live body weight, FCR, and carcass yield) of broiler chickens.

MATERIAL AND METHODS

Extract Preparation

The preparation of the extract was adapted from the method described by Ako-sile et al. (2023). Briefly, 200 g of ground cinnamon (*Cinnamomum verum*) was mixed with 2 L of 36% ethanol. This mixture was macerated for 96 h and then filtered through filter paper. The resulting solution was evaporated in a 55 °C water bath using a rotary vacuum evaporator equipped with a membrane vacuum pump until a constant weight was achieved. After cooling in a refrigerated unit, the pure extract was stored in the dark at 5 °C until IO application.

Hatching Eggs and Incubation

Hatching eggs were obtained from a 34-week-old Ross 308 broiler breeder flock (Czech Republic). Subsequently, the eggs were randomly placed into a BioStream-er 24S setter, where eggshell temperature was monitored. The initial temperature was set at 38.1 °C and gradually decreased to 36.7 °C over the incubation period. At 17.5 DOI, the eggs were candled, and unfertilized eggs or those with dead embryos were discarded. Following the IO treatment, the eggs were transferred to a BioStreamer 8H hatcher, where the temperature was maintained at an average of 36.0 °C until hatching.

In Ovo Treatment

A total of 480 fertile eggs were randomly assigned to two groups: an untreated control group (CG; n = 210) and an experimental group treated with cinnamon extract (EG; n = 270). Based on the findings of Kuka et al. (2023), who reported no differences between uninjected and placebo-injected groups, an untreated control group was selected. A higher number of eggs was intentionally allocated to the EG to ensure a sufficient and representative sample of male chickens for the subsequent growth trial.

The EG was treated via IO injection at 17.5 DOI. A hole was pierced into the shell at the blunt end using a sterile 22G needle. The injection solution was prepared by diluting the stock cinnamon extract with sterile physiological saline (0.9% NaCl) to a final concentration of 9 mg/mL. The application was performed into

the amniotic fluid using a 1-mL syringe equipped with a 23G needle inserted to a depth of approximately 3 cm. Each egg received an injection of 0.2 mL of this solution, delivering a total dose of 1.8 mg of cinnamon extract per egg.

Hatchability and Post-Hatch Management

Hatchability was evaluated for each tray as the percentage of hatched chickens from fertile eggs. After feather sexing, a total of 72 male chickens per group were randomly selected (evenly representing all incubation trays). These birds were distributed into 6 floor pens on wood shaving litter, with 12 chickens per pen. Housing conditions complied with the Ross 308 management guidelines (Aviagen 2025), and water and feed were provided *ad libitum*. The 35-day fattening period included three dietary phases: starter (D1–14), grower (D15–28), and finisher (D29–35). The dietary nutritional composition is presented in Table 1.

Tab. 1: *Nutritional composition of diets (g/kg, on a dry matter basis)*

	Starter	Grower	Finisher
Crude protein	214,44	201,37	175,23
Crude fat	31,94	40,03	43,23
Crude fiber	43,37	34,27	46,80
Crude ash	67,96	56,81	43,28

Growth Performance and Carcass Parameter Evaluation

Cockerels were weighed individually at housing (D1) and weekly until D35 to evaluate BW and body weight gain (BWG) per phase and for the entire trial. Feed intake (FI) was recorded daily per pen to calculate the feed conversion ratio (FCR). Health status was monitored twice daily, and mortality was included in the calculations. At D35, six average birds per group (one per replicate) were weighed and slaughtered to determine carcass weight (excluding neck and feet). Carcass yield was calculated relative to live body weight, and the proportions of skinless breast and thigh muscles were determined based on carcass weight.

Statistical Analysis

Data normality was verified by the Shapiro-Wilk test. Performance (BWG) and feed utilization (FI, FCR) parameters were evaluated via one-way ANOVA with the floor pen as the experimental unit ($n = 6$ per group). For BW, data were analyzed using a linear mixed model (nested ANOVA), with the treatment group as a fixed effect and individual replicates nested within the group as a random effect. This model accounted for the shared pen environment, establishing the replicate as the true statistical unit for individual measurements. Carcass traits were evaluated by one-way ANOVA using one selected bird of average BW from each pen as the statistical unit ($n = 6$ per group). Statistical analyses were performed in Statistica 14. Effects were declared significant at $p < 0.05$, while statistical trends were noted at $p < 0.10$. Results are expressed as means $\pm$ SD (standard deviation).

RESULTS AND DISCUSSION

A crucial indicator of successful embryonic development is the hatchability of fertile eggs, which must not be adversely affected by any IO administration. The results presented in Table 2 demonstrate that IO supplementation with the cinnamon extract solution in the EG did not induce statistically significant changes compared to CG. Although a slightly lower average hatchability was recorded in the EG, this numerical difference was entirely minor from a statistical standpoint, thereby confirming the safety of the applied dose and extract concentration for the developing embryo.

Tab. 2: Hatchability (%) of broiler hatching eggs following in ovo treatment (means $\pm$ SD)

	Group		<i>p</i> -value
	CG (n = 6)	EG (n = 6)	
Hatchability	94.95 $\pm$ 3.65	92.91 $\pm$ 3.46	0.443

No statistically significant differences ($p > 0.05$). Abbreviations: CG = untreated control group; EG = cinnamon extract experimental group (0.2 mL/egg); SD = standard deviation.

Maintaining high hatchability is critical during IO application, as elevated concentrations of EOs can be embryotoxic or restrict oxygen availability by disrupting shell membrane integrity. For instance, EOs from eugenol, clove, tea tree, lemongrass, and thyme are considered unsuitable for IO delivery due to reduced hatchability rates (Khaskheli et al. 2025). Conversely, Bozbay and Göneci (2023) observed no adverse effects on hatchability using a commercial cinnamon extract at doses up to 12 mg/egg, likely due to air cell targeting via a 27G (19 mm) needle. Other cinnamon extract studies (El-Kholy et al. 2021; Akosile et al. 2023) did not report hatchability data, though both also targeted the air cell. In contrast, our study demonstrates that amniotic injection of cinnamon extract at 1.8 mg/egg does not impair the hatching process. This indicates that cinnamaldehyde is well-tolerated at this concentration without inducing fatal metabolic or respiratory disruptions during late incubation.

The development of broiler BW during the 35-day fattening period is presented in Table 3. The data indicate that a single IO application of cinnamon extract had no adverse effects on growth performance. Initial BW at placement (D1) was balanced between groups, and average body weight remained highly consistent throughout the weekly intervals (D7 to D28) without statistically significant deviations. At the end of the trial (D35), the experimental group achieved a numerically higher average weight compared to the control; however, this difference was not statistically significant due to intra-group variability.

In agreement with our findings, Akosile et al. (2023) observed no increase in final BW. In contrast, El-Kholy et al. (2021) reported significantly higher body weight both at hatch and at the end of the fattening period following IO cinnamon extract

Tab. 3: Average body weight (g) of broiler chickens during the 35-day fattening period (means $\pm$ SD)

Age	Group		p-value
	CG (n = 6)	EG (n = 6)	
D1	40.19 $\pm$ 2.71	39.94 $\pm$ 2,87	0.917
D7	160.50 $\pm$ 17.14	160.82 $\pm$ 18.53	0.597
D14	455.19 $\pm$ 56.31	458.55 $\pm$ 51.15	0.582
D21	874.26 $\pm$ 108.15	879.07 $\pm$ 105.87	0.867
D28	1533.27 $\pm$ 158.98	1532.65 $\pm$ 171.15	0.620
D35	2393.75 $\pm$ 254.93	2427.63 $\pm$ 286.84	0.671

No statistically significant differences ($p > 0.05$). Abbreviations: CG = untreated control group; EG = cinnamon ex-tract experimental group (0.2 mL/egg); D = day; SD = standard deviation. Data were analyzed using a linear mixed model based on individual bird weights within each pen (n = 6 per group).

application. Enhanced final BW was also recorded by Oke et al. (2021) after black cumin extract administration.

On the other hand, Meijer et al. (2024) failed to confirm any effects of carvacrol, the main component of oregano EO administered into the amnion at 17.5 DOI, on chicken weight at D7, beyond which the fattening of the Ross 308 broilers did not continue. Regarding dietary alternatives, Qaid et al. (2021) described an increase in Ross 308 body weight at D14 and D21 in the case of in-feed supplementation of cinnamon at a dose of 2 g/kg of feed, with the weight of the broilers being comparable to the antibiotic-treated group.

Average FI per chicken across the growth phases and the entire fattening period is presented in Table 4. Statistical analysis confirmed no significant effect of the IO cinnamon extract application on this criterion, with feed consumption remaining balanced between the CG and EG throughout the entire trial.

The balanced feed intake across the groups clearly demonstrates that the pre-natal intervention via IO application of the cinnamon extract did not compromise the post-hatch appetite of the broilers or the mechanisms regulating feed intake.

Tab. 4: Average feed intake (g/bird) of broiler chickens across different growth phases and the entire fattening period (means $\pm$ SD)

Period	Group		p-value
	CG (n = 6)	EG (n = 6)	
D1-14	491.97 $\pm$ 13.49	497.65 $\pm$ 5.62	0.364
D15-28	1586.97 $\pm$ 37.78	1609.14 $\pm$ 50.53	0.409
D29-35	1502.36 $\pm$ 55.07	1496.60 $\pm$ 58.34	0.864
D1-35	3581.29 $\pm$ 79.32	3603.39 $\pm$ 100.79	0.682

No statistically significant differences ($p > 0.05$). Abbreviations: CG = untreated control group; EG = cinnamon ex-tract experimental group (0.2 mL/egg); D = day; SD = standard deviation.;

Average BWG across the growth phases and the entire fattening period are summarized in Table 5. Consistent with the body weight development, no statistically significant differences in weight gains were recorded between the groups. In the final phase and over the entire trial, the EG exhibited a numerically higher average weight gain compared to the CG, though this trend was not statistically significant.

Tab. 5: Average body weight gain (g/bird) of broiler chickens across different growth phases and the entire fattening period (means $\pm$ SD)

Period	Group		p-value
	CG (n = 6)	EG (n = 6)	
D1-14	414.58 $\pm$ 19.36	418.86 $\pm$ 8.40	0.630
D15-28	1078.86 $\pm$ 58.79	1074.84 $\pm$ 37.87	0.891
D29-35	858.79 $\pm$ 84.76	895.58 $\pm$ 44.61	0.369
D1-35	2416.19 $\pm$ 78.65	2453.24 $\pm$ 60.84	0.383

No statistically significant differences ($p > 0.05$). Abbreviations: CG = untreated control group; EG = cinnamon ex-tract experimental group (0.2 mL/egg); D = day; SD = standard deviation.

The results confirm that the single prenatal supplementation with cinnamon extract does not affect the growth intensity of broilers. While continuous dietary administration of cinnamon often leads to a direct stimulation of weight gains through the modulation of the gut environment (Khan et al. 2025), a single IO application at 17.5 DOI primarily demonstrates its biological safety, as it causes neither embryo damage nor subsequent post-hatch growth depression.

The FCR values in relation to dietary treatment are presented in Table 6. No statistically significant differences were detected between the monitored groups during any of the evaluated periods. In the initial phases (D1-28), feed efficiency was identical between both groups, while a numerical decrease in FCR was observed in the EG compared to the CG during the final week (D29-35).

The stable FCR values confirm that prenatal stimulation with cinnamon extract did not impair nutrient utilization for muscle deposition. The slight, non-significant

Tab. 6: Feed conversion ratio of broiler chickens across different growth phases and the entire fattening period (means $\pm$ SD)

Period	Group		p-value
	CG (n = 6)	EG (n = 6)	
D1-14	1.19 $\pm$ 0.08	1.19 $\pm$ 0.02	0.970
D15-28	1.48 $\pm$ 0.11	1.50 $\pm$ 0.08	0.685
D29-35	1.76 $\pm$ 0.16	1.67 $\pm$ 0.06	0.230
D1-35	1.52 $\pm$ 0.03	1.51 $\pm$ 0.04	0.474

No statistically significant differences ($p > 0.05$). Abbreviations: CG = untreated control group; EG = cinnamon ex-tract experimental group (0.2 mL/egg); D = day; SD = standard deviation.

FCR improvement in the EG during the final week correlates with the numerically higher weight gains observed in the same period (Table 5). Although FCR was not significantly altered in our study, literature indicates that IO cinnamon extract can positively influence this parameter. For instance, El-Kholy et al. (2021) confirmed enhanced feed efficiency following IO administration of aqueous cinnamon, thyme, or clove extracts. Furthermore, Akosile et al. (2023) reported improved FCR values after applying hydroalcoholic extracts of cinnamon and clove.

The results of the carcass analysis on day 35 are presented in Table 7. Although no parameters reached strict statistical significance, a pronounced statistical trend was recorded for two key indicators. Specifically, a trend toward an increased carcass yield was observed in the EG compared to the CG. A similar tendency toward higher values in the experimental group was noted for the breast muscle proportion. Conversely, the thigh muscle proportion remained balanced between both groups without statistical differences.

Tab. 7: *Carcass yield and proportions of main meat cuts in broiler chickens at day 35 (%; means $\pm$ SD)*

	Group		<i>p</i> -value
	CG (n = 6)	EG (n = 6)	
Carcass yield	68.09 $\pm$ 0.59	69.80 $\pm$ 2.03	0.077
Breast muscle	29.77 $\pm$ 1.30	31.94 $\pm$ 2.15	0.060
Thigh muscle	21.48 $\pm$ 1.36	20.38 $\pm$ 1.56	0.222

No statistically significant differences ($p > 0.05$). Abbreviations: CG = untreated control group; EG = cinnamon ex-tract experimental group (0.2 mL/egg); SD = standard deviation.

The recorded statistical trends suggest that prenatal stimulation with cinnamon extract may exert an anabolic effect on broiler muscle development, persisting until slaughter age. This positive trend in breast muscle proportion and carcass yield is likely associated with cinnamaldehyde, which enhances nutrient utilization, amino acid digestibility, and nitrogen retention, thereby favoring muscle tissue deposition (Chowdhury et al. 2018).

CONCLUSION

This study demonstrates the biological safety of prenatal cinnamon extract supplementation into the amnion of broiler chickens. The absence of significant differences indicates that the tested substance neither inhibits growth nor induces embryonic metabolic stress. From a commercial perspective, the observed positive trends in carcass traits suggest promising potential for this method. A single prenatal intervention indicated a tendency to stimulate breast muscle development, representing the economically most valuable cut, which is presumably mediated by the antioxidant properties of the extract. This occurred without restricting overall carcass growth. Given the verified safety of this protocol, extensive opportunities for follow-up research open up. Future studies should focus on the

histological development of the intestinal mucosa, gastrointestinal enzymatic activity, cellular oxidative status, and post-hatch microbiota modulation to fully elucidate the mechanism of action and optimize this method for commercial poultry production.

ACKNOWLEDGEMENT

The project was supported by the Internal Grant Agency of the Faculty of AgriSciences, Mendel University in Brno, no. IGA26-AF-IP-031.

REFERENCES

- Akosile O.A., Sogunle O.M, Majekodunm, B.A. Oke O.E. (2023): In ovo injection of cinnamon or clove alters the physiology and growth of broilers in a hot tropical environment. *Translational Animal Science*. 7(1).
- Ali A., Ponnampalam E.N, Pushpakumara G., Cottrell J.J., Suleria H.A.R. a Dunshea F.R. (2021): Cinnamon: A Natural Feed Additive for Poultry Health and Production—A Review. *Animals*. 11(7).
- Aviagen (2025): Ross 308 FF Broiler Management Handbook. Aviagen Group 2025. Available from: https://aviagen.com/assets/Tech_Cen-ter/Ross_Broiler/Aviagen-ROSS-Broiler-Handbook-EN.pdf
- Bozbay C.K. a Göneci B. (2023): Evaluation of In Ovo Cinnamon, Ginger or Anise Extract Injection on Broiler Hatching Performance. *Black Sea Journal of Agriculture*. 6(3), 226–231.
- Das R., Mishra P. a Jha R. (2021): In ovo Feeding as a Tool for Improving Performance and Gut Health of Poultry: A Review. *Frontiers in Veterinary Science*. 8.
- Ebeid T.A., Ketta M., Al-Homidan I.H., Barakat H. a Abdel-Moneim E., 2023. In ovo feeding of nutraceuticals and its role in adjusting the gastrointestinal tract, antioxidative properties, immunological response, and performance in poultry: An updated review. *Czech Journal of Animal Science*. Online. 68(1), 1–16.
- Elbaz A.M., Ateya A., Youssef S.A.M., Arafa A.S., Sallam M.G., Abdel-AZIZ A., Al-Rasheed M., Babake, M.A., Othman D.O., Gad G.G. a Abdelhady A.R.Y. (2025): Efficacy of in ovo feeding with *Lactobacillus acidophilus* and oregano essential oil in improving growth performance, immunity, microbial enumeration, and gene expression of ostrich chicks. *Livestock Science*. 298, 105723.
- El-Kholy K.H., Sarhan D.M.A a El-Said E.A. (2021): Effect of In-ovo Injection of Herbal Extracts on Post-hatch Performance, Immunological, and Physiological Responses of Broiler Chickens. *Journal of World's Poultry Research*. 11(2), 183–192.
- Chowdhury S., Mandal G.P. a Patra A.K. (2018): Different essential oils in diets of chickens: 1. Growth performance, nutrient utilisation, nitrogen excretion, carcass traits and chemical composition of meat. *Animal Feed Science and Technology*. 236, 86–97.

- Jha R., Singh A.K., Yadav S., Berrocoso J.F.D. a Mishra B. (2019): Early Nutrition Programming (in ovo and Post-hatch Feeding) as a Strategy to Modulate Gut Health of Poultry. *Frontiers in Veterinary Science*. 6, 82.
- Khan K., Al-Khalaifah H., Ahmad N., Khan M.T., Alonaizan R., Khan R.U., Naz S., Abudabos A. a Alhidary I.A. (2025): Dietary supplementa-tion of cinnamon and turmeric powder enhances growth performan-ce, nutrient digestibility, immune response, and renal function in broi-ler chickens. *Poultry Science*. 104(10), 105556.
- Khaskheli A.A., Niknafs S., Meijer M.M.Y., Tan X., Ferket P. R. a Roura E. (2025): The in ovo screening of 27 single essential oils showed selective effects on hatcha-bility, performance and gene ex-pression relevant to gut functions in broilers at hatch. *Poultry Science*. 104(1), 104670.
- Kuka T.T., Bakoma B., Kuka F.C. a Adjei-Mensah B. (2023): In ovo effect of Soursop (*Annona muricata* L.) leaf extract on hatching and post-hatch performance of Noiler chickens. *Veterinary and Animal Science*. 21, 100311.
- Manneck D., Manz G., Braun H.-S., Rosendahl J. a Stumpff F. (2021): The TRPA1 Agonist Cinnamaldehyde Induces the Secre-tion of HCO₃⁻ by the Porcine Colon. *International Journal of Molecular Sciences*. 22(10), 5198.
- Meijer M.M.Y., Van den Brand H., Palmieri Ch., Niknafs S., Khaskhe-li A.A. a Roura E. (2024): Early-life immunomodulation by carvacrol delivered in ovo in broiler chickens. *Poultry Science*. 103(12), 104286.
- Niknafs S., Meijer M.M.Y., Khaskheli A.A. a Roura E. (2024): In ovo delivery of oregano essential oil activated xenobiotic detoxification and lipid metabolism at hatch in broiler chickens. *Poultry Science*. 103(2), 103321.
- Oke O.E., Oyelola O.B., Iyasere O.S., Njoku C.P., Oso A.O., Oso O.M., Fatoki S.T., Bankole K.O., Jimoh I.O., Sybill N.I., Awodipe H.O., Adegbite H.O., Rahman S.A. a Daramola J.O. (2021): In ovo injection of black cumin (*Nigella sativa*) extract on hatching and post hatch performance of thermally challenged broiler chickens during incubation. *Poultry Science*. 100(3), 100831.
- Oyelola O.B., Iyasere O.S., Adeleye O.O. a Oke O.E. (2023): The in-fluence of in ovo feeding of black cumin extract on the physiological responses of broil-ers under hot tropical environments. *Acta Scientia-rum - Animal Sciences*. 46. ISSN 1806-2636.
- Qaid M.M., Al-Mufarrej S.I., Azzam M.M., Al-Garad, M.A., Albaada-ni H.H., Alhidary I.A. a Aljumaah R.S. (2021): Growth Performance, Serum Biochemical Indices, Duodenal Histomorphology, and Cecal Microbiota of Broiler Chickens Fed on Diets Supplemented with Cinnamon Bark Powder at Prestarter and Starter Phases. *Animals*. 11(1), 94.
- Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition.
- Wang J., Deng L., Chen M., Che Y., Li L., Zhu L., Chen G. a Feng T. (2024): Phytogenic feed additives as natural antibiotic alternatives in animal health and produc-tion: A review of the literature of the last decade. *Animal Nutrition*. 17, 244–264.