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The Efficiency of *Urtica dioica* Extract in Feeding of Laying Hens

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ABSTRACT

Currently, poultry specialists are working hard to find feed additives of natural origin. Medicinal plants are a source of a wide range of biologically active compounds with multifunctional effects, including antimicrobial ones. To understand the potential use of various medicinal plants and their extracts in poultry farming, the current study aimed to investigate the effect of feeding different doses of water-ethanol extract of *Urtica dioica* (*Urtica dioica* L.) on the egg productivity of laying hens. A total of 300 laying hens were divided to control and five experimental groups of chickens, each with 5 replicates. During the entire experiment, the laying hens of the control group were fed complete compound feeds according to the egg-laying phase, and the chickens of the experimental groups were additionally fed *Urtica dioica* extract in different doses. The results indicated that feeding laying hens with *Urtica dioica* extract in doses of 5, 10, 15, 20, and 25 mg/kg of body weight had a positive effect on their egg productivity. An increase in egg production per average laying hen in the experimental groups was 2.6-6.1%, and the intensity of egg production was 2.1-5.4%, compared to the control. However, the feed consumption in all experimental groups decreased. When introducing Urtica dioica extract into full-fledged compound feeds for laying hens, there was an increase in the relative egg white content, egg white/egg yolk ratio, and a decrease in relative yolk and shell content. Accordingly, it is suggested to include Urtica dioica extract at a dose of 15 mg/kg in the diet of laying hens which can improve economic efficiency and egg parameters.

Keywords: Chemical composition, Egg morphology, Egg production, Feed conversion, Medicinal plant

INTRODUCTION

In recent decades, poultry specialists have been actively interested in the use of plant-based additives in poultry feeding, which can provide high zootechnical indicators, improve the safety of poultry, and contribute to the normalization of metabolism (Abilov et al., 2021; Butt et al., 2022). On the other hand, the modern conditions of the industry necessitate the use of drugs that do not cause drug resistance and have a multifunctional effect. Phyto-biotics, including feed additives derived from *Urtica dioica* medicinal plant (*Urtica dioica* L.), can be effective in this regard. The interest in *Urtica dioica* for its use in feeding poultry is associated with the content of a significant amount of biologically active compounds in its leaves, which can cause different positive effects. Thus, *Urtica dioica* leaves contain terpenoids (Gül et al., 2012) and carotenoids (Kukric et al., 2012), including β-carotene, neoxanthin, violaxanthin, lutein, and lycopene (Guil-Guerrero et al., 2003), fatty acids, especially palmitic, cis-9,12-linoleic and α-linolenic acids (Bağci, 2002; Guil-Guerrero et al., 2003), various polyphenolic compounds (Rutto et al., 2013; Orcic et al., 2014), essential amino acids, chlorophyll, vitamins, tannins, carbohydrates, sterols, polysaccharides, isolectins (Guil-Guerrero et al., 2003; Sajfrtová et al., 2005; Kukric et al., 2012), and minerals (Kara, 2009), the most important of which is iron. A study conducted by Augspole et al. (2017) showed that *Urtica dioica* was richer in individual polyphenols, compared to other wild plants. The advantage of *Urtica dioica* leaves in the content of phenolic compounds,

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compared to dandelion leaves, was found by Ghaima et al. (2013). Rutin is noted by Vajic et al. (2015) as the predominant phenolic compound in nettle leaves. According to Nasiri et al. (2011), *Urtica dioica* is the only plant containing choline acetyltransferase synthesizing acetylcholine.

Urtica dioica contains various compounds with antioxidant action, including terpenoid phenol, flavonoids, alpha-tocopherol, and ascorbic acid (Surai et al., 2019). Carvacrol and carvone are the main terpenoids of nettle with antioxidant, growth-stimulating, antibacterial, and antiviral effects (Upton, 2013). Terpenoids and phenolic compounds in *Urtica dioica* suppress oxidative stress through different mechanisms, such as inhibition of lipid peroxidation, activation of antioxidant enzymes, chelation of metals, and an increase in uric acid levels (Behrooj et al., 2012).

Several studies have found that biologically active compounds of *Urtica dioica* can exhibit stronger antibacterial activity than synthetic antimicrobial drugs. Modarresi-Chahardehi et al. (2012) considered the antimicrobial activity of nine extracts of *Urtica dioica* obtained by various methods using organic solvents. Of nine extracts, four types suppressed the growth of Gram-negative and five types could inhibit Gram-positive bacteria. Ethyl acetate extracts of *Urtica dioica* showed the highest antimicrobial activity. Some studies have indicated that the use of *Urtica dioica* in feeding farm animals and poultry has a positive effect on their productivity, resistance, and the state of the microbiota of the gastrointestinal tract (Wenk, 2000).

The use of extracts obtained from *Urtica dioica* in poultry diet is of particular interest. In this regard, the current study aimed to determine the optimal doses of *Urtica dioica* extract in mixed feed for the egg productivity of chickens.

MATERIALS AND METHODS

Ethical approval

The study was conducted and certified based on the ethical rules of Kuzbass State Agricultural Academy, Russia.

Study design

The research was carried out on laying hens (Hisex White cross breed) of a poultry farm located in Kuzbass, Russia, aged 49 weeks. A total of 300 laying hens were randomly selected from the study area and were divided into five experimental groups and one control group. Each group had 5 replicates, including 10 laying hens. The hens were managed based on the last recommendations of the management guidelines of the breed during the study.

When dividing laying hens into groups, the age and body weight of laying hens were taken according to the requirements of the methodology developed in VNITIP (Rinttilä and Apajalahti, 2013). The chickens were fed with a full-fledged compound feed according to the egg-laying phase. The chickens of the experimental groups were additionally fed *Urtica dioica* extract in different doses based on the main biologically active compounds of the plant (Devkota et al., 2022). Laying hens of the first, second, third, and fourth experimental groups received *Urtica dioica* at 5, 10, 15, 20, and 25 mg/kg of body weight, respectively.

Urtica dioica extract was obtained through water-ethanol extraction. It contains flavonoids (in terms of quercetin, 4.26%), 2.53% ascorbic acid, 1.17% caffeic acid, 0.25% ferulic acid, 0.12% carotenoids, and 0.005% coumarins (in terms of scopoletin). The number of biologically active compounds met the requirements of regulatory agents (Bagno et al., 2019). The experiment lasted 6 months. The average egg-laying and the average egg weight were calculated according to the previous study by Rinttilä and Apajalahti (2013). The safety of the chickens was evaluated as a percentage of the initial livestock for the entire period of the research.

The morphological and chemical compositions of eggs were determined according to previously accepted methods (Rinttilä and Apajalahti, 2013; Tikhomirov and Fomin, 2018). The contents of moisture, protein, fat, and ash were determined in the collected egg sample.

The European Efficiency Coefficient (EEC) was used to assess the efficiency of egg production:

$$\text{EEC} = (1{,}4 \times egg\ mass\ per\ head, kg) - (0{,}35 \times feed\ conversion, kg)$$

Economic efficiency was determined by the Poultry Egg Production Efficiency Index (PEPEI; Kavtarashvili, 2015):

$$\text{PEPEI} = \frac{(E \text{ x } ASe) + (M \times Pm)}{(Cf \text{ x } 100 : Sf) + Cgr} \text{ x } 100$$

An increase in the above indices, expressed in units, indicates an increase in the efficiency of egg production.

Where, E denotes the gross yield of eggs (pcs), ASe describes the average selling price of 1 egg (rub), M signifies the gross yield of meat in slaughter weight (kg), Pm is the average selling price of 1 kg of meat (rub), Cf refers to the total cost of feed for the productive period (rub), Sf represents the share of feed in the cost of eggs in percentage, and Cgr is the cost of growing replacements (rub).

Statistical analysis

The obtained data were analyzed by standard statistical methods using SPSS Software Version 22. The data in the tables below are presented in the form of Mean (M) ± Standard Error of the Mean (SEM). The reliability of the differences between the control group and each of the experimental groups was assessed by the Student's t-test. The results at $p < 0.05$ were considered significant.

RESULTS AND DISCUSSION

The results of this study on the effect of feeding different doses of *Urtica dioica* extract on the egg productivity of laying hens are presented in Table 1 and Figure 1. The chickens fed a diet containing *Urtica dioica* extract had higher egg production for the initial and average laying in the experimental groups than chickens in the control group ($p > 0.05$). This production rate increased by 2.7% in the first group, 5.3% and 6.6% in the second group, 8.2% and 6.1% in the third group, 3.6% and 2.6% in the fourth group, and 7.8% and 6.1% in the fifth group. A similar finding was reported by Bruneel et al. (2013), indicating the higher intensity of egg production in the five experimental groups, compared to the control by 2.2, 5.4, 5.0, 2.1, and 5.0%, respectively. The average egg weight rates of laying hens of the first to the third experimental groups were 0.8%, 2.3%, and 1.4%, respectively, and the fourth and fifth experimental groups were 2.6% and 1.0%, which were less than the control group ($p > 0.05$).

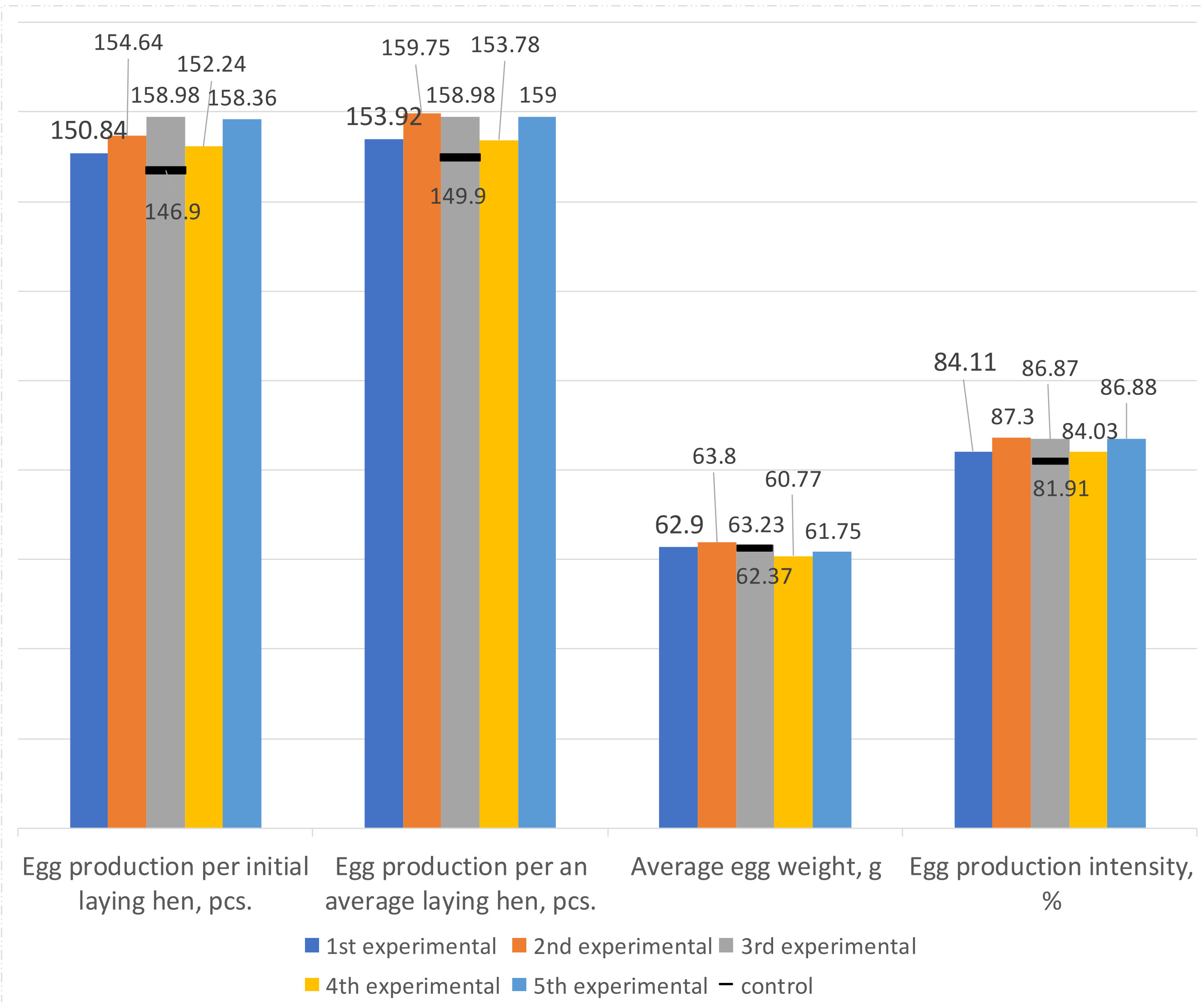

Figure 1. Indicators of egg productivity of laying hens aged 49 weeks consumed different levels of *Urtica dioica* extract

Table 1. The effects of different levels of *Urtica dioica* extract on the performance of laying hens aged 49 weeks

Indicator \ Group	Control	1	2	3	4	5
Safety (%)	94	94	92	100	96	98
Feed consumption per group (kg)	1125	1130.37	1150.50	1111.60	1073.70	1081.82
Feed consumption per 1 head (kg)	22.96	23.07	23.77	22.23	21.69	21.72
Feed conversion per 10 eggs	1.53	1.50 (-2%)*	1.49 (-2.6%)*	1.40 (-8.5%)*	1.41 (-7.8%)*	1.37 (-10.5%)*
Feed conversion per 1 kg of egg mass	2.46	2.38 (-3.2%)*	2.33 (-5.3%)*	2.21 (-10.2%)*	2.32 (-5.7%)*	2.21 (-10.2%)*

*compared to the control group results, %

Table 2. The eggs contents of lying hens aged 49-week-old fed different levels of *Urtica dioica* extract

Parameters \ Group	Control	1	2	3	4	5
Shell thickness (mm)	0.403 ± 0.009	0.401± 0.008	0.407 ± 0.020	0.393 ± 0.022	0.373 ± 0.004*	0.377 ± 0.014
Egg White (%)	57.11 ± 0.99	57.72 ± 0.86	58.40 ± 0.73	59.04 ± 0.64	59.67 ± 0.58*	60.36 ± 0.59*
Egg Yolk (%)	30.19 ± 0.92	29.59 ± 0.77	28.99 ± 0.63	28.38 ± 0.51	27.76 ± 0.44*	27.13 ± 0.48**
Egg Shell (%)	11.09 ± 0.46	11.08 ± 0.42	11.00 ± 0.38	10.98 ± 0.39	10.96 ± 0.40	10.89 ± 0.45
Egg white/egg yolk ratio	1.91 ± 0.09	1.96 ± 0.08	2.02 ± 0.06	2.09 ± 0.06	2.16 ± 0.05*	2.23 ± 0.05**

The safety of laying hens in the third, fourth, and fifth experimental groups was higher than 100, 96, and 98%, respectively, and it was 92% in the second experimental group, which was less than the control hens (94%).

The feed consumption per group in the first and second experimental groups was more than the control, third, fourth, and fifth groups, respectively, compared to the control. Therewith, the feed conversion per 10 eggs in all experimental groups decreased by 2%, 2.6%, 8.5%, 7.8%, and 10.5%, respectively, compared to the control ($p > 0.05$). In all experimental groups, the conversion of feed per 1 kg of egg mass decreased compared to the control group ($p > 0.05$). According to Langhout (2000), Madrid et al. (2003), Alçiçek et al. (2004), and Zhang et al. (2005), *Urtica dioica* extracts may have properties that stimulate appetite and digestion.

The morphological composition of eggs is presented in Table 2. There was a significant decrease in eggshell thickness in the fourth experimental group compared to the control group ($p < 0.05$).

When feeding hens with *Urtica dioica* extract, there was a significant increase in the relative egg white content of the eggs in the fourth and fifth experimental groups compared to the control group ($p < 0.05$), and a decrease in the relative yolk content in the fourth and fifth experimental groups, compared to the control group ($p < 0.05$). The relative content of the shell decreased insignificantly compared to the control group, and the egg white/yolk ratio was elevated significantly in the fourth and fifth experimental groups compared to the control group ($p < 0.05$).

When feeding *Urtica dioica* extract to laying hens, the ash content in the eggs of chickens in the experimental groups did not significantly differ from that of the control group ($p > 0.05$; Figure 2). There was a decrease in protein content in the samples of the first, second, third, and fifth experimental groups by 0.02%, 0.04%, 0.06%, 0.10%, and an increase in the fourth experimental group by 0.69%. The water and fat content in the eggs of chickens of the experimental groups was lower than the control group ($p > 0.05$).

The efficiency indices of chicken egg production are presented in Table 3.The EEC of egg production, which characterizes a set of indicators, such as egg mass per 1 laying hen and feed conversion per 1 kg of egg mass, was higher when feeding the *Urtica dioica* extract to the experimental groups (the first to fifth) by 0.49, 1.22, 1.07, 0.03, 0.74 units, respectively. In PEPEI of laying hens, the parameters of the full technological cycle of poultry production, were higher in the experimental chickens, compared to the control when using *Urtica dioica* extract in the first to fifth experimental groups by 1.18%, 0.93%, 6.76%, 4.17%, 6.71%, respectively.

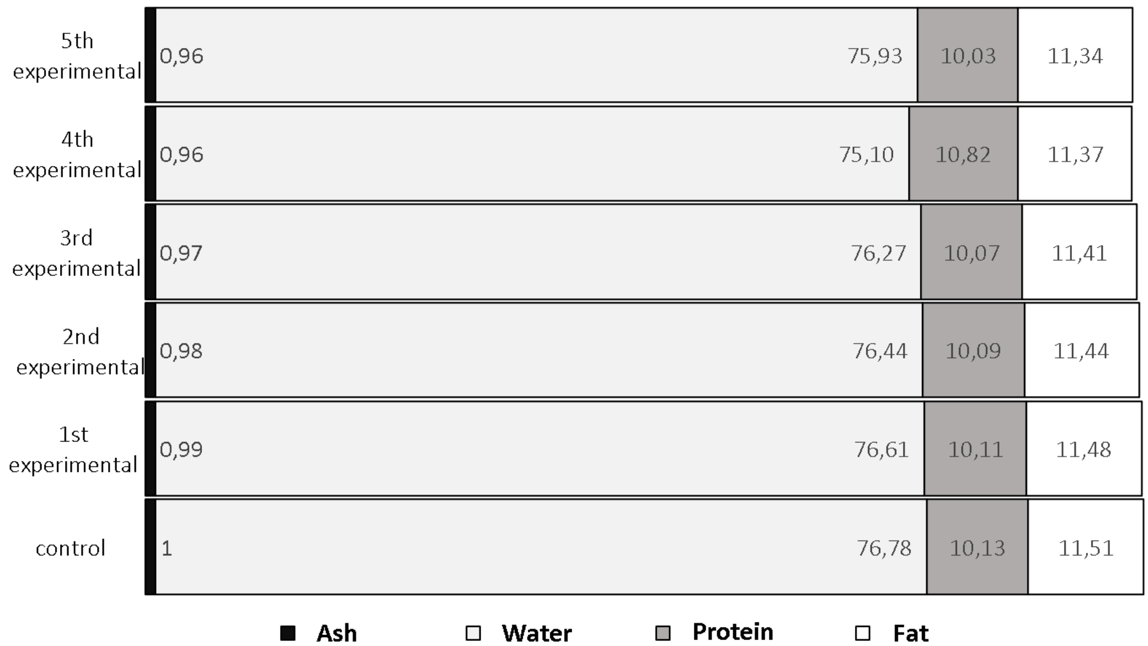

Figure 2. Chemical composition of chicken eggs that used different levels of *Urtica dioica* extracts.

Table 3. Indicators of the efficiency of the production of chicken eggs when feeding *Urtica dioica* extracts

Factor \ Group	Control	1	2	3	4	5
EEC (unit)	12.23	12.72	13.45	13.30	12.26	12.97
PEPEI (unit)	100.82	102.0	101.75	107.58	104.99	107.53

EEC: European Efficiency Coefficient, PEPEI: Poultry Egg Production Efficiency Index

The results of the current research in the main provisions are consistent with the results obtained by researchers on the use of *Urtica dioica* in feeding laying hens. Thus, it was found in another study by Hosseini Mansoub (2011) that the use of *Urtica dioica* in the diets of laying hens in the amount of 0.75-2.0% of the feed weight had a significant effect on the productivity and quality of eggs.

Grela et al. (2013) indicated that *Urtica dioica* positively affected the growth and egg-laying of laying hens, and improved the color and taste of egg yolk.

The addition of *Urtica dioica* to the diet of laying hens in an amount of 1 g/kg of live weight in combination with a feed additive from Mukhor-Talin zeolite in an amount of 5% of the dry feed weight increased the safety by 4%, and the intensity of egg production by 1.3% (Luzbaev, 2010).

CONCLUSION

The findings of the present study indicated the use of *Urtica dioica* extracts at a dose of 15 mg/kg of body weight in feeding laying hens contributed to a significant increase in the production and improved the egg parameters.

DECLARATIONS

Authors' contributions

All the authors contributed to conducting the study, collecting data, statistical analysis, and writing the article.

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Ethical considerations

The authors confirmed that attended to all ethical issues, including misconduct, plagiarism, consent to publish, falsification, double publication or submission have been checked by the authors very carefully.

Availability of data and materials

The related data of this study will be available upon request to the authors of this article.

Competing interests

The authors had no competing interests.

REFERENCES

Abilov BT, Marynich AP, Boldareva AV, and Nechaev SA (2021). Efficiency of protein-rich plant and animal additives in feeding broiler chickens. IOP Conference Series: Earth and Environmental Science, 624: 012052. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/624/1/012052/pdf

Bruneel C, Lemahieu C, Fraeye I, Ryckebosch E, Muylaert K, Buyse J, and Foubert I (2013). Impact of microalgal feed supplementation on omega-3 fatty acid enrichment of hen eggs. Journal of Functional Foods, 5(2): 897-904. DOI: https://www.doi.org/10.1016/j.jff.2013.01.039

Butt KY, Nadeem N, Ghori MI, Zain H, and Kanwal N (2022). Analysis of Trigonella foenum-graecum seeds, Musa paradisiaca, and Citrus sinensis peels as a poultry feed supplement. Pakistan Journal of Life and Social Sciences, 20(1): 45-51. Available at: http://www.pjlss.edu.pk/pdf_files/2022_1/45-51.pdf

Alçiçek A, Bozkurt M, and Çabuk M (2004). The effects of an essential oil combination derived from selected herbs growing wild in Turkey on broiler performance. South African Journal of Animal Science, 33(2): 89-94. DOI: https://www.doi.org/10.4314/sajas.v33i2.3761

Augspole I, Duma M, Ozola B, and Cinkmanis I (2017). Phenolic profile of fresh and frozen nettle, goutweed, dandelion, and chickweed leaves. Proceedings of the 11th Baltic Conference on Food Science and Technology, Food Science and Technology in a Changing World, Jelgava, Latvia, pp. 27-28. Available at: https://www.llu.lv/sites/default/files/files/lapas/FoodBalt_2017_Abstract_book_0.pdf

Bağci E (2002). Fatty acid composition of the aerial parts of *Urtica dioica* (*Stinging nettle*) L. (Urticaceae). In: B. Şener (Editor), Biodiversity. Springer., Boston, MA. pp. 323-327. Available at: https://link.springer.com/chapter/10.1007/978-1-4419-9242-0_40#citeas

Bagno O, Shevchenko S, Shevchenko A, Izhmulkina E, Prokhorov O, and Petruchenko A (2019). Egg productivity in the quails fed on the extract of calendula officinalis. International Journal of Innovative Technology and Exploring Engineering, 8(10): 4108-4112. Available at: https://www.ijitee.org/wp-content/uploads/papers/v8i10/J98560881019.pdf

Behrooj N, Khajali F, and Hassanpour H (2012). Feeding reduced-protein diets to broilers subjected to hypobaric hypoxia is associated with the development of pulmonary hypertension syndrome. British Poultry Science, 53(5): 658-664. DOI: https://www.doi.org/10.1080/00071668.2012.727082

Devkota HP, Paudel KR, Khanal S, Baral A, Panth N, Adhikari-Devkota A, Jha NK, Das N, Singh SK, Chellappan DK et al. (2022). Stinging nettle (*Urtica dioica* L.): Nutritional composition, bioactive compounds, and food functional properties. Molecules, 27(16): 5219. DOI: https://www.doi.org/10.3390/molecules27165219

Ghaima KK, Hashim NM, and Ali SA (2013). Antibacterial and antioxidant activities of ethyl acetate extract of nettle (*Urtica dioica*) and dandelion (Taraxacumofficinale). Journal of Applied Pharmaceutical Sciences, 3(5): 96-99. Available at: https://japsonline.com/admin/php/uploads/904_pdf.pdf

Grela E, Klebaniuk R, Kwiecie´n M, and Pietrzak K (2013). Fitobiotyki w produkcji zwierzecej [Phytobiotics in animal production]. Przegląd Hodowlany, 3: 21-24. Available at: http://ph.ptz.icm.edu.pl/wp-content/uploads/2016/12/10-Grela.pdf

Guil-Guerrero JL, Rebolloso-Fuentes MM, and Isasa MET (2003). Fatty acids and carotenoids from stinging nettle (*Urtica dioica* L.). Journal of Food Composition and Analysis, 16(2): 111-119. DOI: https://www.doi.org/10.1016/S0889-1575(02)00172-2

Gül S, Demirci B, Baser KHC, Akpulat HA, and Aksu P (2012). Chemical composition and *in vitro* cytotoxic, genotoxic effects of essential oil from *Urtica dioica* L. Bulletin of Environmental Contamination and Toxicology, 88: 666-671. DOI: https://www.doi.org/10.1007/s00128-012-0535-9

Hosseini Mansoub N (2011). Effect of nettle (*Urtica dioica*) on performance, quality of eggs, and blood parameters of laying hens. Advances in Environmental Biology, 5(9): 2718-2721. Available at: http://www.aensiweb.com/old/aeb/2011/2718-2721.pdf

Kara D (2009). Evaluation of trace metal concentrations in some herbs and herbal teas by principal component analysis. Food Chemistry, 114(1): 347-354. DOI: https://www.doi.org/10.1016/j.foodchem.2008.09.054

Kukric ZZ, Topalic-Trivunovic LN, Kukavica BM, Matoš SB, Pavicic SS, Boroja MM, and Savic AV (2012). Characterization of antioxidant and antimicrobial activities of nettle leaves (*Urtica dioica* L.). Acta Periodica Technologica, 43: 257-272. Available at: http://www.doiserbia.nb.rs/Article.aspx?ID=1450-71881243257K

Langhout P (2000). New additives for broiler chickens. World Poultry, 16(3): 22-27. Available at: https://www.cabdirect.org/cabdirect/abstract/20001416551

Luzbaev KV (2010). The use of feed additives from natural zeolite and *Urtica dioica* for laying hens. Vestnik Buryatskoi GSKhA, 3: 33-35.

Madrid J, Hernández F, García V, Orengo J, Megías MD, and Sevilla V (2003). Effect of plant extracts on ileal apparent digestibility and carcass yield in broilers at level of farm. 14th European Symposium on Poultry Nutrition, Lillehammer, Norway. p. 187.

Modarresi-Chahardehi A, Ibrahim D, Fariza-Sulaiman S, and Mousavi L (2012). Screening antimicrobial activity of various extracts of *Urtica dioica*. Revista de Biología Tropical, 60(4): 1567-1576. DOI: https://www.doi.org/10.15517/rbt.v60i4.2074

Nasiri S, Nobakht A, and Safamehr A (2011). The effect of different levels of nettle *Urtica dioica* L. (Urticaceae) medical plant in starter and grower feeds on performance, carcass traits, blood biochemical and immunity parameters of broilers. Iranian Journal of Applied Animal Sciences, 1(3): 177-181. Available at: https://www.sid.ir/paper/576168/en

Orcic D, Franciškovic M, Bekvalac K, Svircev E, Beara I, Lesjak M, and Mimica-Dukic N (2014). Quantitative determination of plant phenolics in *Urtica dioica* extracts by high-performance liquid chromatography coupled with tandem mass spectrometric detection. Food Chemistry, 143: 48-53. DOI: https://www.doi.org/10.1016/j.foodchem.2013.07.097

Rinttilä T and Apajalahti J (2013). Intestinal microbiota and metabolites—Implications for broiler chicken health and performance. Journal of Applied Poultry Research, 22(3): 647-658. DOI: https://www.doi.org/10.3382/japr.2013-00742

Rutto LK, Xu Y, Ramirez E, and Brandt M (2013). Mineral properties and dietary value of raw and processed stinging nettle (*Urtica dioica* L.). International Journal of Food Science, 2013: 857120. DOI: https://www.doi.org/10.1155/2013/857120

Sajfrtová M, Sovová H, Opletal L, and Bártlová M (2005). Near-critical extraction of β-sitosterol and scopoletin from stinging nettle roots. The Journal of Supercritical Fluids, 35(2): 111-118. https://www.doi.org/10.1016/j.supflu.2004.12.008

Surai PF, Kochish II, Fisinin VI, and Kidd MT (2019). Antioxidant defense systems and oxidative stress in poultry biology: An update. Antioxidants, 8(7): 235. DOI: https://www.doi.org/10.3390/antiox8070235

Tikhomirov AI and Fomin AA (2018). Macroeconomic factors in realizing export potential for animal production. International Agricultural Journal, 3: 27-39. Available at: https://cyberleninka.ru/article/n/macroeconomic-factors-in-realizing-export-potential-for-animal-production

Upton R (2013). Stinging nettles leaf (*Urtica dioica* L.): Extraordinary vegetable medicine. Journal of Herbal Medicine, 3(1): 9-38. DOI: https://www.doi.org/10.1016/j.hermed.2012.11.001

Vajic UJ, Grujic-Milanovic J, Živkovic J, Šavikin K, Gođevac D, Miloradovic Z, Bugarski B, and Mihailovic-Stanojevic N (2015). Optimization of extraction of stinging nettle leaf phenolic compounds using response surface methodology. Industrial Crops and Products, 74: 912-917. Available at: https://www.cabdirect.org/cabdirect/abstract/20153316829

Wenk C (2000). Why all the discussion about herbs?. Proceedings of Alltech's 16th Anniversary Symposium Biotechnology in the Feed of Industry. Nottingham University Press. UK. pp. 79-96. Available at: https://cir.nii.ac.jp/crid/1572261550698764928

Zhang KY, Yan F, Keen CA, and Waldroup PW (2005). Evaluation of microencapsulated essential oils and organic acids in diets for broiler chickens. International Journal of Poultry Science, 4(9): 612-619. Available at: https://scialert.net/abstract/?doi=ijps.2005.612.619