

## MACLEAYA CORDATA IN POULTRY NUTRITION

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### Abstract

*The increasing resistance of bacteria to antibiotics combined with consumer aversion to growth promoters in animal feeding is driving the search for natural and safe substitutes. Phytotherapeutics are a generally acceptable group of feed additives. One of the many plants in which these can be found is the Asian-origin *Macleaya cordata*, also known as the five-seeded plume poppy, which belongs to the poppy family (*Papaveraceae*). These plants contain alkaloids, predominantly sanguinarine. This paper presents a species-by-species overview of the most important research results concerning the use of *Macleaya cordata* plant extract supplements in poultry nutrition. The effect of the use of *Macleaya cordata* extracts in poultry feeding has been extensively studied on the basis of species such as chickens, turkeys, Japanese quails and rock doves. It is to be noted that formulas containing *Macleaya cordata* extracts improve the overall bird health and production parameters through benefitting their digestive and immune systems. This is an extremely desirable effect, especially at a time when efforts are underway to completely eliminate antibiotics from poultry feeding and find natural alternatives.*

*Keywords: *Macleaya cordata*, phytotherapeutic, nutrition*

### Introduction and literature review

The increasing resistance of bacteria to antibiotics combined with consumer aversion to growth promoters in animal feeding is driving the search for natural and safe substitutes. Phytotherapeutics, i.e. active plant-based substances, are a generally acceptable group of feed additives. One of the many plants in which these can be found is the Asian-origin five-seeded plume poppy (*Macleaya cordata*), which belongs to the poppy family (*Papaveraceae*). Poppies contain alkaloids, predominantly sanguinarine. Sanguinarine is found not only in *Macleaya cordata*, but also in other plants, such as the bloodroot (*Sanguinaria canadensis*), *Bocconia frutescens* as well as the well-known greater celandine (*Chelidonium majus*). Other alkaloids, such as chelerythrine, sangulutine, chelilutine, chelirubine and sanguirubine, are also present in the composition of poppy plants (Simanek, 1985; Tschirner, 2004; Mackraj et al., 2008). Jeroch et al. (2009) list the following effects of sanguinarine preparations on monogastric livestock: blocking microbial enzymes that break down amino acids in the gastrointestinal tract, positive effects on protein metabolism, increased activity of digestive

enzymes or organs that produce them, anti-inflammatory properties, support of the immune system and antimicrobial activity.

Studies on the effects of preparations containing *Macleaya cordata* extracts on body function have so far been conducted on a wide variety of livestock species. Pigs have been studied by Tschirner et al. (2003), Gudev et al. (2004), Van Leeuwen (2016), Rundle and Stein (2018), aquaculture by Rairat et al. (2013), Imanpoor et al. (2015), and rodents and lagomorphs by Zdarilova et al. (2008), Teillet et al. (2012). However, most attention has been paid to the effect of *Macleaya cordata* extract on the production performance of poultry. Most of the studies focused on chickens (*Gallus gallus domesticus*), with some of the work also devoted to turkeys (*Meleagris gallopavo*), Japanese quails (*Coturnix japonica*) and common pigeons (*Columba livia*). The following is a species-by-species overview of the most important works on the subject.

### **The use of *Macleaya cordata* in chicken nutrition**

The use of *Macleaya cordata* extracts in the feeding of broiler chickens has been relatively well studied. Juśkiewicz et al. (2011) evaluated the effect of adding an alkaloid extract from *Macleaya cordata* on growth rates, caecal microbiota activity and the fatty acid profile of breast muscles in Cobb chicken broilers. *Macleaya cordata* extract in the form of a ready-to-use commercial preparation, at 15 mg/kg of feed, was added to the experimental diet, while the control diet contained none of it. Chicken broilers were put on a diet as described above for five weeks from birth. No increased weight gain was observed in the birds that ate feed with *Macleaya cordata* extract. However, a positive effect of the addition of the tested preparation on the metabolic activity of caecal microbiota was noted, compared to the control group, with the activity of potentially harmful  $\beta$ -glucuronidase and  $\beta$ -glucosidase decreased, and the activity of bacterial enzymes such as  $\alpha$ -glucosidase,  $\alpha$ -galactosidase and  $\beta$ -galactosidase increased. Higher concentrations of short-chain fatty acids in the caecum led to a favourable decrease in the pH of the contents passing through this section of the digestive tract in broilers on the experimental diet. It was also observed that the addition of the experimental preparation had a positive effect on the content of fatty acids in the breast muscles of birds in the experimental group – the quantity of monounsaturated fatty acids increased, while the quantity of polyunsaturated fatty acids decreased. In conclusion, it was found that the addition to chicken diet of a preparation containing *Macleaya cordata* extract has a favourable effect on the caecal fermentation processes in broiler chickens, but has no significant effect on body weight gain.

Zhang et al. (2022) conducted an experiment to investigate the effects of *Macleaya cordata* extract and oregano oil on growth and immune response in broilers. One-day-old chickens were divided into four groups. The control group received basic feed and water on an *ad libitum* basis. The other three received water supplemented with a solution of *Macleaya cordata* extract, oregano oil and both, respectively. It was noted that the group supplemented with both substances showed a significantly higher production performance compared to the control group. That group also saw an improvement in biochemical and antioxidant parameters of blood serum. An elongation of intestinal villi was also observed, indicating a positive effect of the added preparations on intestinal function. *Macleaya cordata* extract and oregano oil were found to have an extremely beneficial effect on the health of chicken broilers for superior production performance.

Research has also been conducted on the effect of *Macleaya cordata* extract on the nutrition of layer hens. Wang et al. (2022b) tested the effect of the addition of *Macleaya cordata* extract and *bacillus* cultures on the improvement of egg yield by regulating reproductive hormones, intestinal microbiota and the intestinal barrier in layer hens. Hens

aged 29 weeks were tested. The birds were divided into a control group, fed on basic feed, and three experimental groups, fed on diets with *Macleaya cordata* extract, a probiotic mixture of *Bacillus* and both additives, respectively. The results showed that egg yield and average egg weight were significantly higher in the group fed a diet containing both *Macleaya cordata* extract and probiotic *Bacillus* cultures, compared to the other groups. This group also had significantly higher serum FSH hormone values and increased FSH-related receptor activity in the ovaries, as well as a more effective intestinal epithelial barrier and higher caecal concentrations of acetic acid and butyric acid. The bodies of the birds in this group also had better antioxidant capacity, as demonstrated by elevated catalase enzyme activity and expression of genes related to inflammatory response and apoptosis. Thus, it was shown that the addition of *Macleaya cordata* extract had a positive effect on productivity and digestive tract function in layer hens.

The experiment by Matulka et al. (2018) aimed to test the effect of supplementing the diet of layer hens with a preparation containing *Macleaya cordata* extract, on their health and productivity. The birds were divided into four groups – a control group, fed on basic feed, and three experimental groups, to whose diets 100 mg/kg, 500 mg/kg and 1,000 mg/kg of the test preparation were added, respectively. The experiment lasted 56 days. No statistically significant differences were recorded between the experimental groups and the control group in terms of body weight, daily feed intake or feed conversion rate. The groups eating feed with 500 mg and 1,000 mg of the test preparation per kg of feed, respectively, showed an increase in egg yield compared to the control group, but no differences in egg size. A dissection of the experimental animals found no pathological changes attributable to the use of the preparation. No measurable quantities of sanguinarine or chelerythrine (substances found in *Macleaya cordata*) were detected in the eggs of hens fed the experimental diets. That study proved that the addition of a preparation containing *Macleaya cordata* extract at a proportion of 1,000 mg/kg of feed has no negative effect on the productivity and health of layer hens, while improving egg yield.

In addition to the experimental results presented above, hens were also used to study other issues related to the effects of *Macleaya cordata* extract on body function. For example, Zduńczyk et al. (2010) described the effect of this preparation and its components on meat traits, Juśkiewicz et al. (2013) discussed its influence on gastrointestinal microbiota activity, and Wang et al. (2022a) addressed its impact on heat stress resistance. Research also covered bird tolerance to this plant extract (Matulka et al., 2014) as well as its possible use in the treatment of necrotic enteritis (Xue et al., 2017). All of the above experiments demonstrated a beneficial effect of the addition of *Macleaya cordata* extract on the studied parameters.

### **The use of *Macleaya cordata* in turkey nutrition**

Studies on the efficacy of *Macleaya cordata* extract have also been conducted on turkeys. Manaa et al. (2022) addressed the effects of *Macleaya cordata* on productivity, growth-related gene expression as well as haematological and biochemical blood parameters in turkeys. One-day-old turkeys were divided into groups. For the first two weeks of the experiment, they were all fed an identical feed for acclimatisation purposes and then each group was put on a different diet until they were 20 weeks old. The experimental diets contained a preparation with *Macleaya cordata* extract at proportions of 25, 50 and 100 mg/kg of feed, respectively, while the control diet contained none of it. There were no statistically significant differences between the groups in terms of bird growth and productivity. Also, no negative effects were observed for haematological parameters such as haemoglobin levels or red and white blood cell counts, or for biochemical parameters related to normal kidney and liver function. However, increased expression was observed in genes

responsible for body growth in birds eating diets containing the preparation, especially in the 50 mg/kg group. These were genes encoding traits such as gonadotropin-releasing hormone receptor (GHR), insulin-like growth factor 1 (IGF-1), adenine nucleotide translocase (ANT), cyclooxygenase 3 (COX-3) or thermogenin 3 (UCP-3). In conclusion, it was found that the addition of *Macleaya cordata* extract had a positive effect on the expression of growth-related genes in turkeys, with no negative effect on haematological or biochemical blood parameters.

### **The use of *Macleaya cordata* in quail nutrition**

Quails have also been investigated for the effects of *Macleaya cordata* extract on birds. The experiment, which was carried out by Amaral et al. (2021), aimed to study the location, distribution and quantification of nerve plexuses in intestinal smooth muscles in quails eating feed with varying quantities of *Macleaya cordata* extract. One-day-old female quails were divided into four groups and then fed one of four diets for 35 days. Three diets were enriched with *Macleaya cordata* extract as a commercial preparation at proportions of 50, 100 and 150 mg/kg of feed, respectively. The fourth was the control diet and contained no extract. The study showed no effect of *Macleaya cordata* extract on the quantitative population of enteric nerve cells, but it was noted that it increased neuronal activity compared to the control group. This suggested that the feed remained in the gastrointestinal tract for a longer period of time, allowing the body to absorb more nutrients, and so the production parameters of these birds were also improved.

Karakçı et al. (2022) examined the effect of feeds enriched with a mixture of aromatic plant extracts, including *Macleaya cordata* extract, on egg yield, egg quality, blood biochemical parameters and antioxidant status of layer Japanese quails. Birds at 12 weeks of age were divided into four groups; the experiment lasted for 10 weeks. The control group was fed basic feed without plant extract mixtures, while the other three were fed experimental diets in which plant extract mixture was added at proportions of 100, 150 and 200 mg/kg of feed, respectively. The eggs from the experimental groups, examined at the end of the experiment, differed significantly in terms of parameter values in comparison with the control group. Egg weight and shell thickness were highest in the group fed a diet containing a plant extract mixture at 100 mg/kg of feed. Considerably higher values were recorded for protein quality measured in Haugh units, egg white index, egg yolk index and yolk colour intensity in the quail groups on the experimental diets. These groups of birds also showed blood serum values indicative of the antioxidant effect of *Macleaya cordata* extract, such as elevated levels of superoxide dismutase (SOD) and reduced levels of free malondialdehyde (MDA). The addition of aromatic plant extracts was found to have a positive effect on the egg yield in Japanese quails, as well as on their antioxidant status.

### **The use of *Macleaya cordata* in pigeon nutrition**

The effect of *Macleaya cordata* extract has also been studied in common pigeons. In their study, Hu et al. (2016) deal with the effect of *Macleaya cordata* extract on growth and immune function in young pigeons. Young pigeons aged ten days were divided into seven groups. The first was the control group fed with basic feed. The diets of three experimental groups were enriched with *Macleaya cordata* powder at concentrations of 30, 40 and 50 mg/kg of feed, respectively; the diets of the fourth and fifth groups were enriched with 40 mg/kg *Macleaya cordata* extract PE50 containing the alkaloids:  $\alpha$ -allocryptine and  $\beta$ -allocryptine and 40 mg/kg of extract BE60, containing sanguinarine and chelerythrine, respectively; the diet of the sixth group was enriched with chlorotetracycline at 150 mg/kg of feed. The experiment lasted 15 days. There was no significant difference between the

experimental groups and the control group in terms of the daily growth of young pigeons or feed intake. There were also no statistically significant changes in the bursa of Fabricius index or thymus index. The spleen index was significantly higher in the groups fed with 40 mg/kg *Macleaya cordata* extract PE50 and 50 mg/kg *Macleaya cordata* powder in comparison with the other groups. The pancreas index was significantly higher in birds from the group fed a diet with 50 mg/kg *Macleaya cordata* powder compared to pigeons from the control group and the groups fed with 30 mg/kg *Macleaya cordata* powder and 150 mg/kg chlortetracycline. In the group eating the diet with 40 mg/kg of *Macleaya cordata* extract PE50, significantly higher total protein levels were recorded compared to the group fed with 150 mg/kg chlortetracycline. The low-density lipoprotein content was significantly lower in the group of pigeons fed with 30 mg/kg *Macleaya cordata* powder compared to the control group. The above results indicated that the addition of *Macleaya cordata* extract has a positive effect on the immune system of young pigeons and is a valuable dietary supplement.

Krzykawski et al. (2022) investigated the effect of adding *Macleaya cordata* extract to drinking water on the reproductive performance of pigeons and their level of parasite infection during the mating season. Twenty pairs of homing pigeons were divided into two groups – control and experimental. The experimental group received a preparation containing *Macleaya cordata* extract at 1 g/10 litres in their drinking water every day. Parameters such as the number of eggs laid and fertilised, and chicks hatched and reared to 30 days of age were analysed. In addition, faeces were collected three times from each adult bird for parasitological examination. It was noted that the birds in the experimental group had slightly higher reproductive performance and lower levels of endoparasite infection compared to the control group. The experiment showed that the addition of *Macleaya cordata* extract to drinking water resulted in a trend towards better reproductive performance and lower levels of endoparasite infection in pigeons.

Table 1 provides an overview of studies on the use of *Macleaya cordata* extract preparations in the feeding of different poultry species, broken down by additive form and quantity.

Table 1. Studies on the use of *Macleaya cordata* extract doses in the feeding of various poultry species – a review

Gatunek drobiu Poultry species	Forma dodatku Form of additive	Ilość dodatku Amount of additive	Autorzy Authors
Brojlery kurze Broiler chickens	Wyciąg w postaci komercyjnego, sypkiego preparatu Extract in the form of loose commercial preparation	30 mg/kg paszy 30 mg/kg of feed	Zduńczyk i in. (2010)
		30 mg/kg paszy 30 mg/kg of feed	Juśkiewicz i in. (2013)
		1000 mg/kg paszy 1000 mg/kg of feed	Wang i in. (2022a)
		100 mg/kg paszy 100 mg/kg of feed	Matulka i in. (2014)
		100 mg/kg paszy 100 mg/kg of feed	
		500 mg/kg paszy 500 mg/kg of feed	
		1000 mg/kg paszy 1000 mg/kg of feed	
		150 mg/kg paszy 150 mg/kg of feed	Xue i in. (2017)
		15 mg/kg paszy 15 mg/kg of feed	Juśkiewicz i in. (2011)
		125 ml/1000 l wody 125 ml/1000 l of water	Zhang i in. (2022)
Kury nioski Laying hens	Wyciąg w postaci komercyjnego, sypkiego preparatu lub w mieszaninie z kulturami bakterii probiotycznych Extract in the form of loose commercial preparation or as a mixture with cultures of probiotic bacteria	0,6 mg/kg paszy 0.6 mg/kg of feed	Wang i in. (2022b)

	Wyciąg w postaci komercyjnego, sypkiego preparatu Extract in the form of loose commercial preparation	100 mg/kg paszy 100 mg/kg of feed 500 mg/kg paszy 500 mg/kg of feed 1000 mg/kg paszy 1000 mg/kg of feed	Matulka i in. (2018)
Indyki Turkeys	Wyciąg w postaci komercyjnego, sypkiego preparatu Extract in the form of loose commercial preparation	25 mg/kg paszy 25 mg/kg of feed 50 mg/kg paszy 50 mg/kg of feed 100 mg/kg paszy 100 mg/kg of feed	Manaa i in. (2022)
Przepiórki Quails	Wyciąg w postaci komercyjnego, sypkiego preparatu Extract in the form of loose commercial preparation	50 mg/kg paszy 50 mg/kg of feed 100 mg/kg paszy 100 mg/kg of feed 150 mg/kg paszy 150 mg/kg of feed	Amaral i in. (2021)
	Sypka mieszanka różnych wyciągów roślinnych Loose mixture of various plant extracts	100 mg/kg paszy 100 mg/kg of feed 150 mg/kg paszy 150 mg/kg of feed 200 mg/kg paszy 200 mg/kg of feed	Karakçı i in. (2022)
Gołębie mięsne Meat pigeons	Susz z całej rośliny Whole dried plant	30 mg/kg paszy 30 mg/kg of feed 40 mg/kg paszy 40 mg/kg of feed 50 mg/kg paszy 50 mg/kg of feed	Hu i in. (2016)
	Wyciąg PE50* Extract PE50*	40 mg/kg paszy 40 mg/kg of feed	
	Wyciąg BE60** Extract BE60**	40 mg/kg paszy 40 mg/kg of feed	
Gołębie pocztowe Homing pigeons	Wyciąg w postaci komercyjnego, sypkiego preparatu Extract in the form of loose commercial preparation	1 g/10 l wody 1 g/10 l of water	Krzykowski i in. (2022)

\* Zawiera alkaloidy  $\alpha$ -allokryptynę i  $\beta$ -allokryptynę.\* Contains alkaloids  $\alpha$ -allocryptine and  $\beta$ -allocryptine.

\*\* Zawiera alkaloidy sangwinarynę i chelerytrynę.\*\* Contains alkaloids sanguinarine and chelerythrine

## Summary

In conclusion, the effect of the use of *Macleaya cordata* extract in poultry nutrition has been extensively studied on the basis of species such as chickens, turkeys, quails and pigeons. It is important to note that formulations containing *Macleaya cordata* extracts improve the overall health and production parameters of birds, with beneficial effects on their digestive and immune systems. This is a highly desirable effect, especially at a time when antibiotic resistance is rising and consumers have a preference for products derived from animals raised without the use of antibiotics.

## References

- Amaral P.F.G.P.D., Trindade W.A., Favetta P.M., Geronimo E., Silva I.C.D., Serenini G.D.F., Palin G.C., Urano T.K., Oliveira J.M.D.M., Reati L.D.A., Dias J.C.P., Otutumi L.K., Soares A.A., Germano R.D.M. (2021). Location, distribution, and quantification of myenteric plexus neurons of the jejunum of quails fed with different levels of commercial *Macleaya cordata* extract. *Cienc. Rural*, 51(11): 1e20200844-10.
- Gudev D., Popova-Ralcheva S., Moneva P., Bonovska M., Valchev G., Valcheva A. (2004). Effect of supplemental Sangrovit on some biochemical indices and leukocytes phagocytic activity in growing pigs. *Arch. Zoot.*, 7: 16–26.

- Hu X., Hou Z., Guo M., Tan C., Chen Y. (2016). Effects of *Macleaya cordata* extracts on growth performance and immune function of hatchlings. *Chin. J. Anim. Nutr.*, 28(6): 1783–1788.
- Imanpoor M.R., Salaghi Z., Roohi Z., Beikzadeh A., Davoodipoor A. (2015). Effect of herbal supplement of Sangrovit on growth, blood biochemical parameters, survival and resistance to salinity stress of *Cyprinus carpio* fingerlings. *Iran. Sci. Fish. J.*, 24(3): 13–22.
- Jeroch H., Kozłowski K., Jeroch J., Lipiński K., Zduńczyk Z., Jankowski J. (2009). Efficacy of the phytogenic (*Papaveraceae*) additive Sangrovit® in growing monogastric animals. *Züchtungskunde*, 81(4): 279–293.
- Juškiewicz J., Gruzauskas R., Zduńczyk Z., Semaskaite A., Jankowski J., Totilas Z., Jarule V., Sasyte V., Zduńczyk P., Raceviciute-Stupeliene A., Svirmickas G. (2011). Effects of dietary addition of *Macleaya cordata* alkaloid extract on growth performance, caecal indices and breast meat fatty acids profile in male broilers. *J. Anim. Physiol. Anim. Nutr.*, 95(2): 171–178.
- Juškiewicz J., Zduńczyk Z., Gruzauskas R., Dauksienie A., Raceviciute-Stupeliene A., Totilas Z. (2013). Comparative effects of dietary phytobiotic (*Macleaya cordata* alkaloid extract) and probiotic (*Pediococcus acidilactici* MA 18/5 M) preparations as single supplements or in combination on fermentative processes in the broiler chickens caeca. *Vet. Med. Zoot.*, 62 (84): 50–55.
- Karakçı D., Çetin I., Çetin E., Yeşilbağ D. (2022). Effects of aromatic plant extract mixture on laying efficiency, egg quality and antioxidant status in laying quails. *Ank. Univ. Vet. Fak. Derg.*, 69(1): 61–68.
- Krzykawski A., Gugolek M., Gugolek A. (2022). Effect of drinking water supplementation with *Macleaya cordata* extract on reproductive performance of pigeons and prevalence of endoparasitic infections during the breeding season. *Rocz. Nauk. Zoot.*, 49(2): 157–169.
- Mackraj I., Govender T., Gathiram P. (2008). Sanguinarine. *Cardiovasc. Drug Rev.*, 26: 75–83.
- Manaa E.A., Abdel-Latif M.A., Ibraheim S.E., Sakr A., Dawood M., Albadrani G.M., El-Kott A.F., Abdel-Daim M.M., Shafik B.M. (2022). Impacts of *Macleaya cordata* on productive performance, expression of growth-related genes, hematological, and biochemical parameters in turkey. *Front. Vet. Sci.*, 9: 873951.
- Matulka R., Von Alvensleben S., Morlacchini M. (2014). Tolerance and residue study for standardized *Macleaya cordata* extract added to chicken feed. *Int. J. Poult. Sci.*, 13(7): 368–373.
- Matulka R., Von Alvensleben S., Morlacchini M., Fusconii G. (2018). Tolerance study for standardized *Macleaya cordata* extract added to chicken layer diet. *Open J. Anim. Sci.*, 8(1): 104–117.
- Rairat T., Chuchird N., Limsuwan C. (2013). Effect of Sangrovit WS on growth, survival and prevention of *Vibrio harveyi* in rearing of Pacific white shrimp (*Litopenaeus vannamei*). *J. Fish. Environ.*, 37(1): 19–29.
- Rundle C.M., Stein H.H. (2018). 283 Effects of Sangrovit® Extra on apparent ileal digestibility of amino acids, crude protein, acid hydrolyzed ether extract and starch by weanling pigs fed corn-soybean meal diets. *J. Anim. Sci.*, 96 (Suppl. 2): 152–152.
- Simanek V. (1985). Benzophenanthridine alkaloids. In: *The Alkaloids*. Ed. A. Brossi, Academic Press, New York, pp. 185–234.
- Teillet B., Colin M., Lebas F., Alvensleben S.V., Bezille H., Prigent A. (2012). Performance of growing rabbits fed diets supplemented with Sangrovit® in interaction with the feeding plan. *Proc. of 10th World Rabbit Congress, Sharm El Sheikh, Egypt. 3-6.08. 2012*, pp. 531–535.

- Tschirner K., Susenbeth A., Wolfram S. (2003). Influence of Sangrovit® supplementation on nitrogen balance and feed intake in growing pigs. R. Schubert et al. (eds) Proc. of 9th Symposium “Vitamine und Zusatzstoffe in der Ernährung von Mensch und Tier”, Jena/Thüringen, Germany. 24-25.08.2003, pp. 275–279.
- Tschirner K. (2004). Untersuchungen zur Wirksamkeit und zum Nachweis des pflanzlichen Alkaloids Sanguinarin beim Schwein. (Ph.D. thesis), Christian-Albrechts Universität Kiel.
- Van Leeuwen J.I. (2016). Using plant alkaloids in animal feed to improve gut health and FCR. Inter. Pig Topics, 31(7): 19–21.
- Wang M., Zhang J., Huang X., Liu Y., Zeng J. (2022a). Effects of dietary *Macleaya cordata* extract on growth performance, biochemical indices, and intestinal microbiota of yellow-feathered broilers subjected to chronic heat stress. Animals, 12(17): 2197.
- Wang F., Zou P., Xu S., Wang Q., Zhou Y., Li X., Tang L. Wang B., Jin Q., Yu D., Li W. (2022b). Dietary supplementation of *Macleaya cordata* extract and *Bacillus* in combination improve laying performance by regulating reproductive hormones, intestinal microbiota and barrier function of laying hens. J. Anim. Sci. Biotechnol. 13(1): 118.
- Xue G.D., Wu S.B., Choct M., Pastor A., Steiner T., Swick R.A. (2017). Impact of a *Macleaya cordata*-derived alkaloid extract on necrotic enteritis in broilers. Poult. Sci., 96(10): 3581–3585.
- Zdarilova A., Vrublova E., Vostalova J., Klejdus B., Stejskal D., Proskova J., Kosina P., Vecera R., Hrbac J., Cernochova D., Vicar J., Ulrichova J., Simanek V. (2008). Natural feed additive of *Macleaya cordata*: safety assessment in rats a 90-day feeding experiment. Food Chem. Toxicol., 46(12): 3721–3726.
- Zduńczyk Z. Gruzauskas R., Juškiewicz J., Semaskaite A., Jankowski J., Godycka-Klos I., Jarule V., Mieželiene A., Alencikiene G. (2010). Growth performance, gastrointestinal tract responses, and meat characteristics of broiler chickens fed a diet containing the natural alkaloid sanguinarine from *Macleaya cordata*. J. Appl. Poult. Res., 19(4): 393–400.
- Zhang Ch., Li W., Chen L., Chen Z., Wang X., Xu Q., Zhang H., Chen H., Liu J. (2022). Oregano oil combined with *Macleaya cordata* oral solution improves the growth performance and immune response of broilers. Animals, 12(18): 2480.