

Protective effect of ashwagandha (*Withania somnifera*) on glyphosate induced toxicity in body weight and selected organs of Kuroiler birds

K. Kalai* and S. Baruah

Department of Veterinary Pathology, College of Veterinary Sciences and A.H., R.K. Nagar, West, Tripura - 799 008

Address for Correspondence

K. Kalai, Associate Professor, E-mail: kanikakalai@gmail.com

ORCID Id: 0000-0002-8013-6498

Received: 4.3.26; Accepted: 3.4.26

ABSTRACT

The present study evaluated the toxic effects of glyphosate and the ameliorative potential of *Withania somnifera* (ashwagandha/ Indian ginseng) powder on growth performance and organ integrity in kuroiler birds. A total of 75 birds were observed over a period of three months for changes in body weight and pathological alterations in the lungs, brain, spleen, pancreas and gastrointestinal tract (proventriculus, gizzard and intestine). Orally glyphosate-exposed birds exhibited a significant reduction ($p < 0.05$) in body weight gain compared to control and Ashwagandha-supplemented groups. The growth suppression was associated with marked gross and histopathological lesions in the examined organs, indicating systemic cellular stress and tissue damage. In contrast, birds co-administered with Ashwagandha showed significant improvement in body weight and reduced severity of pathological alterations. High-performance liquid chromatography (HPLC) analysis of liver, kidneys, brain and skeletal muscle samples did not detect residues of the parent glyphosate compound. This finding suggests possible rapid metabolism or elimination of glyphosate, or that tissue damage may be mediated by its metabolites rather than by persistence of the parent compound. The study demonstrates the systemic toxic potential of glyphosate exposure and highlights the protective efficacy of Ashwagandha as a natural ameliorative agent against herbicide-induced toxicity in poultry.

Key words: Ashwagandha, Glyphosate, Growth performance, Histopathology, HPLC, Kuroiler

INTRODUCTION

Glyphosate is one of the most widely used herbicides worldwide¹ and its extensive application in agriculture has raised concerns regarding its potential toxic effects on non-target organisms including birds². Exposure to glyphosate through contaminated feed, drinking water or environmental residues may result in systemic toxicity mediated through oxidative stress, cellular degeneration and disruption of normal physiological functions. Free-range birds such as Kuroiler, a widely reared dual-purpose backyard poultry breed in India, are particularly vulnerable due to their scavenging nature and close interaction with the external environment. Such exposure poses a potential threat to growth performance, immune competence and organ integrity in poultry.

Ashwagandha (*Withania somnifera*) is widely regarded as the Indian ginseng. It is a well-known medicinal herb with strong antioxidant, anti-inflammatory and tissue-protective properties^{3&4}. It has been traditionally used to improve reproductive health and enhance stress tolerance. The withanolides present in *W. somnifera* are known to inhibit lipid peroxidation by their antioxidant properties^{5&6}. Being a highly valued drug in ayurveda, it was decided to explore the utility of ashwagandha in combating glyphosate induced toxicity in kuroiler birds. So, the present study was undertaken to evaluate the toxico-pathological effects of glyphosate and to assess the ameliorative potential of ashwagandha supplementation on growth performance and organ integrity in Kuroiler birds.

MATERIALS AND METHODS

Ethical Approval for Animal Studies

The experiment was conducted for a period of three months to

How to cite this article : Kalai, K. and Baruah, S. 2026. Protective effect of ashwagandha (*Withania somnifera*) on glyphosate induced toxicity in body weight and selected organs of Kuroiler birds. Indian J. Vet. Pathol., 50(3) : 236-242.

determine the effects of chronic toxicity of glyphosate in Kuroiler chickens and its amelioration by ashwagandha. The study was carried out after obtaining prior approval from the Institutional Animal Ethics Committee (IAEC), College of Veterinary Science, Assam Agricultural University (AAU), Khanapara, Guwahati, Assam (Approval No. 770/ac/CPCSEA/FVSc/AAU/IAEC/17-18/559 dated 09.08.2017). All experimental procedures were performed in accordance with CPCSEA guidelines for the care and use of experimental animals.

Experimental design

A total of 75 kurolier birds aged three months were selected for the study. Birds were maintained under standard management conditions and were provided with standard pellet feed and clean drinking water ad libitum. The birds were kept under constant observation throughout the experimental period. The birds were randomly divided into three groups, each consisting of 25 birds. Group I served as control and provided with standard pellet feed and clean drinking water. Group II was administered glyphosate (field grade glyphosate, HIJACK, 41% glyphosate SL; Insecticide India Ltd., Rajasthan) was used for induction of experimental toxicity orally at a dose rate of 27.8 mg/kg body weight daily for a period of three months. The dose was calculated based on a pilot study conducted for LD₅₀ estimation as per OECD guideline 425^{7,8}. Group III was administered glyphosate along with ashwagandha powder (Baidyanath Ayurved Ltd.) supplementation at the rate of 0.5% of feed and was provided daily throughout the experimental period⁹. Body weight was measured in the electronic measuring device and recorded at weekly intervals.

Histopathology

Tissue samples from brain, spleen, heart, lungs, proventriculus, gizzard, intestine and pancreas were collected for histopathological examination. Collected samples were fixed in 10% neutral buffered formalin and processed by standard routine histopathological procedure. The paraffin embedded tissue sections were cut at 4–5 µm thickness and stained with Haematoxylin and Eosin (H&E) for microscopic examination¹⁰. Histopathological lesions were graded on a semi-quantitative scale of 0 to 3, where 0 = normal, 1 = mild, 2 = moderate and 3 = severe, based on the extent and severity of tissue alterations.

High profile liquid chromatography (HPLC)

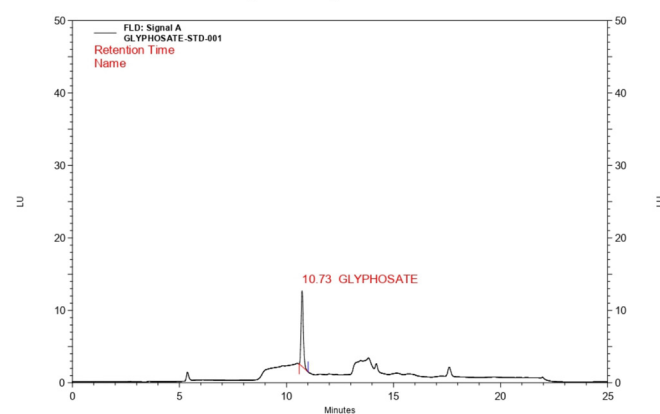
Tissues from liver, kidneys, brain and muscle were collected in plastic pouch and transferred to laboratory in ice packs and stored in deepfreeze (at -20°C) for HPLC to detect the presence of glyphosate parent compounds¹¹. The sample was processed and derivatized at the Department of Veterinary Pharmacology and Toxicology, CVS, AAU, Khanapara. HPLC was performed at Biotech Park, IIT, Guwahati. One gram of chicken tissue (liver, kidney, brain and muscle) was finely minced and transferred into a 250 mL volumetric flask. A mixture of water and methanol (4:1, v/v) was added and the contents were mixed using a circular tube rotator for 1 h. The homogenate was centrifuged at 4000 rpm for 15 min and the supernatant was collected. The supernatant was mixed with an equal volume of methanol, vortexed and centrifuged again at 4000 rpm for 30 min. The final supernatant was diluted fivefold with distilled water. For derivatization, 1 mL of the extract was taken in a 15 mL polypropylene tube.

To this, 0.25 mL of 50 mM borate buffer (pH 9.5) and 0.3 mL of 2 g/L FMOC-Cl (Sigma aldrich) in acetonitrile were added and vortex mixed. The reaction mixture was kept overnight at room temperature. The reaction was terminated by adding 0.3 mL of 2% phosphoric acid. The final solution was filtered through a 0.2 µm syringe filter and analysed by HPLC. A UHPLC machine with fluorescent detector was used with a C18 reverse phase HPLC column (ACE 5 µm 4.6x 250 mm). Elution was done with a mobile phase consisting of 50 mM phosphate buffer (pH 2.5) and HPLC grade acetonitrile. Flow rate was fixed at 0.8 ml/min. Fluorescence detection set at emission wavelength 270 nm with excitation at 325 nm. The standard solution of glyphosate (Glyphosate, analytical grade, Sigma Aldrich, Bangalore) was prepared by dissolving 2 mg of glyphosate in 10 ml of HLC grade water in a graduated glass tube. Working standard solutions of 0.05, 1.0, 2.0, 4.0 and 8.0 mg/ml were prepared by diluting standard solution with appropriate volume of HPLC grade water. The glyphosate solutions were then derivatized with FMOC-Chloride overnight. Then filtered through 0.2 mm syringe filter and injected into UHPLC and standard curve was prepared as shown in the Fig. 1.

Statistical analysis

The data generated from the experiment were subjected to statistical analysis using GraphPad Prism software. Results were expressed as mean ± standard error (SE). The differences among groups were analysed by one-way analysis of variance (ANOVA)

Data File: C:\Users\Admin\Desktop\BIOTECHJUN\Result\FLD\GLYP-111217.seq0012017-12-11
11-39-03 (GMT +05:30).rslt\GLYPHOSATE-STD-001.dat
Method: C:\Users\Admin\Desktop\BIOTECHJUN\Result\FLD\GLYP-111217.seq0012017-12-11
11-39-03 (GMT +05:30).rslt\GLYPHOSATE CALIB.met
Acquired: 11-12-2017 11:41:10 (GMT +05:30)
Printed: 02-01-2018 10:42:12 (GMT +05:30)



FLD: Signal A

Results

Retention Time	Area	Area %	Height	Height %
10.728	12436148	100.00	1744745	100.00
Totals	12436148	100.00	1744745	100.00

Fig. 1. Glyphosate standard curve.

and students t test. Values of $P < 0.05$ and $P < 0.01$ were considered statistically significant and highly significant respectively¹².

RESULT

The weekly mean body weights of birds are presented in Table 1 and Fig. 1. Body weight increased progressively in all groups during the experimental period; however, the control group consistently recorded higher mean body weight than the treated groups. The mean body weight in group II differed significantly ($P < 0.05$) and highly significantly ($P < 0.01$) from the 3rd to 10th week when compared to the groups I and III. During the 11th and 12th weeks, the mean body weight showed a highly significant difference ($P < 0.01$) among all three groups.

The macroscopical examination in Group II birds predominantly exhibited pulmonary congestion

Table 1. Body weight (mean $\pm$ SE).

Time of weighing (week)	Body weight (Kg)		
	Group I	Group II	Group III
1	1.05 $\pm$ 0.02	1.07 $\pm$ 0.02	1.04 $\pm$ 0.02
2	1.34 $\pm$ 0.01	1.24 $\pm$ 0.01*	1.27 $\pm$ 0.02
3	1.59 $\pm$ 0.01	1.35 $\pm$ 0.02**	1.53 $\pm$ 0.01
4	1.76 $\pm$ 0.02	1.50 $\pm$ 0.02**	1.67 $\pm$ 0.03
5	1.88 $\pm$ 0.02	1.58 $\pm$ 0.02**	1.83 $\pm$ 0.02
6	2.10 $\pm$ 0.03	1.68 $\pm$ 0.02**	2.04 $\pm$ 0.02
7	2.32 $\pm$ 0.04	1.83 $\pm$ 0.02**	2.26 $\pm$ 0.03
8	2.48 $\pm$ 0.05	1.97 $\pm$ 0.03**	2.38 $\pm$ 0.03
9	2.63 $\pm$ 0.05	2.10 $\pm$ 0.03**	2.48 $\pm$ 0.03
10	2.71 $\pm$ 0.06	2.21 $\pm$ 0.02**	2.56 $\pm$ 0.03
11	2.89 $\pm$ 0.06	2.29 $\pm$ 0.02**	2.68 $\pm$ 0.04
12	3.12 $\pm$ 0.06**	2.37 $\pm$ 0.02**	2.76 $\pm$ 0.04

* $P < 0.05$, ** $P < 0.01$

Table 2. Comparative lesion scoring (Group II vs Group III).

Organ	Group II (Glyphosate)	Group III (Glyphosate+Ashwagandha)
Lungs	2.00 $\pm$ 0.12*	1.00 $\pm$ 0.08
Brain	1.50 $\pm$ 0.10*	1.00 $\pm$ 0.07
Spleen	1.75 $\pm$ 0.11*	1.00 $\pm$ 0.09
Pancreas	2.00 $\pm$ 0.13*	1.00 $\pm$ 0.08
Heart	1.00 $\pm$ 0.09*	0.50 $\pm$ 0.05
Proventriculus	2.00 $\pm$ 0.12*	1.00 $\pm$ 0.07
Gizzard	2.00 $\pm$ 0.11*	1.00 $\pm$ 0.08
Intestine	2.00 $\pm$ 0.14*	1.00 $\pm$ 0.09

and haemorrhages (Fig. 3). Splenic involvement was characterized by splenomegaly, late-stage pallor and infarction (Fig. 4). Myocardial petechial haemorrhages (Fig. 5) and cerebral vascular congestion and swelling (Fig. 6) found in later stages of the experiment. In the gastrointestinal tract, a thin kaolin membrane adhered to the gizzard mucosa and moderate haemorrhages in the caecal tonsils (Fig. 7). In group III birds the gross lesions

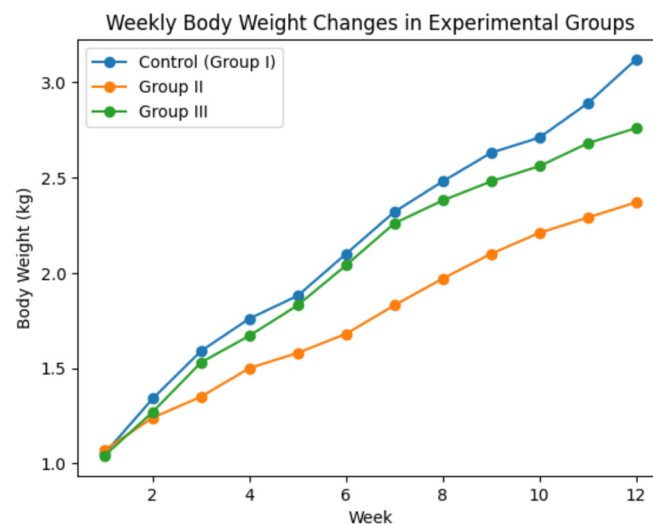


Fig. 2. Changes in body weight in experimental groups.

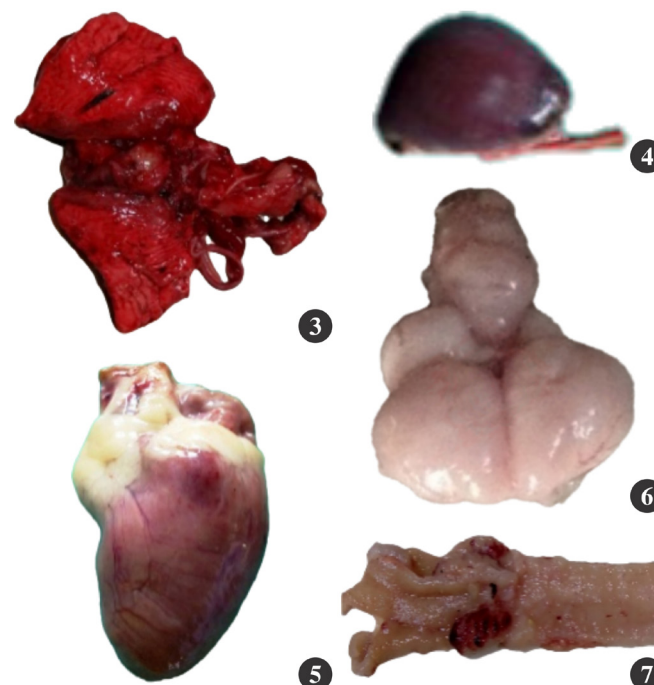
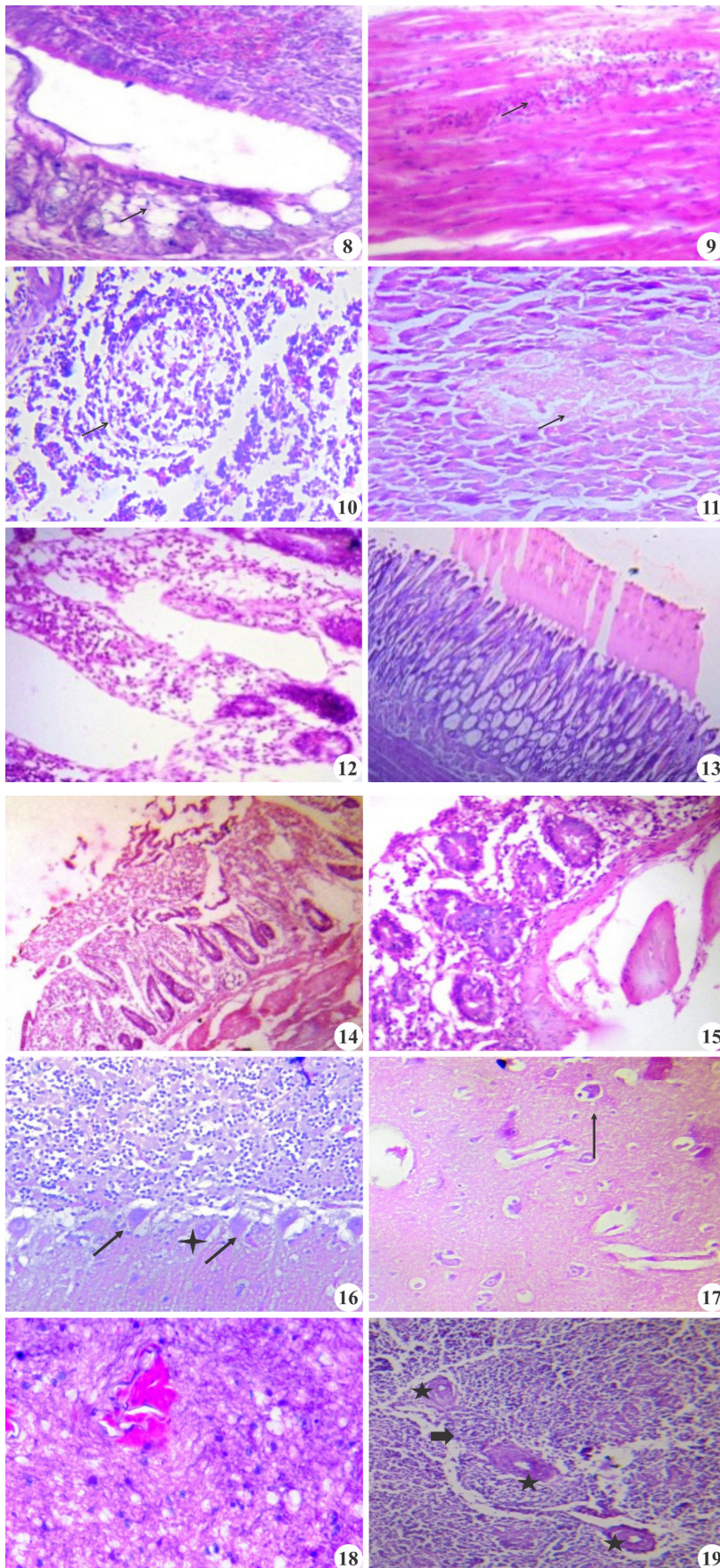


Fig. 3. Photograph showing congestion in lungs (group II); **Fig. 4.** Photograph showing swelling of cerebrum (group II); **Fig. 5.** Heart showing focal petechial haemorrhage in myocardium (group II); **Fig. 6.** Infarct in spleen (group II); **Fig. 7.** Photograph showing haemorrhage in caecal tonsil (group II).



were not observed in all the organs.

Microscopical examination of lungs in group II revealed haemorrhage, congestion and emphysema, perivascular aggregation of mononuclear cells, bronchial lymphoid hyperplasia. (Fig. 8) Heart sections revealed focal myocardial inflammatory infiltration (Fig. 9). Depletion of lymphoid tissue observed in spleen (Fig. 10). Pancreatic islets appeared granular and degenerated (Fig. 11). Proventriculus showed cellular necrosis, haemorrhage and epithelial sloughing (Fig. 12). Gizzard exhibited decreased keratinoid layer and sloughing of koilin membrane (Fig. 13). Intestine showed desquamation of epithelium and necrotic debris and increased secretory cells in large intestine (Fig. 14 & 15). Brain sections showed congestion, vacuolation, neuronophagia and degeneration of Purkinje cells (Fig. 16-18). Spleen revealed formation of secondary lymphoid follicles and thickening of blood vessels in group III birds (Fig. 19). Histopathological lesion scores were significantly higher ($p < 0.05$) in glyphosate-treated birds (Group II) compared to the Ashwagandha-supplemented group (Group III) across all examined organs. The absence of lesions in Group III indicates a significant protective effect of Ashwagandha against glyphosate-induced tissue damage.

In the present study glyphosate parent compound was not detected in any of the

Fig. 8. Mild hypertrophy of bronchial epithelium in lungs (H&E stain 400X); **Fig. 9.** Focal cellular infiltration in myocardium (H&E stain 100X, group II); **Fig. 10.** Spleen (Group II) Depletion of lymphoid follicles (H&E stain 100X); **Fig. 11.** Pancreas (Group II) showing degeneration in Islets of Langerhans (H&E stain 400X); **Fig. 12.** Proventriculus showing necrotic secretory cells (H&E stain 400X); **Fig. 13.** Gizzard, less keratinoid material in gastric pit and sloughing of kaolin membrane (H&E stain 100X); **Fig. 14.** Intestine showing sloughing and desquamation (H&E stain 100X); **Fig. 15.** Large intestine increase in secretory cells (H&E stain 100X); **Fig. 16.** Degeneration in Purkinje cells. Pyknosis of nucleus (star), Karyolysis (arrow) (Group II, H&E 400X); **Fig. 17.** Perinuclear vacuolation and neuronophagia in cerebrum (arrow) (Group II, H&E 400X); **Fig. 18.** Congestion in brain (Group II, H&E 400X); **Fig. 19.** Spleen (Group III) showing thickening of blood vessels and formation of secondary lymphoid follicles (H&E stain 100X).

External Standard Report

Data File: C:\Users\Admin\Desktop\BIOTECH\JUN\Result\FLD\GLYP-111217.seq0012017-12-11 11-39-03 (GMT +05-30).rsf\SAMPLE-L5
 Method: C:\Users\Admin\Desktop\BIOTECH\JUN\Result\FLD\GLYP-111217.seq0012017-12-11 11-39-03 (GMT +05-30).rsf\GLYPHOSATE CALIB.met
 Acquired: 11-12-2017 15:19:00 (GMT +05:30)
 Printed: 02-01-2018 10:50:07 (GMT +05:30)

Sample Amt: 1
 Multiplier: 1

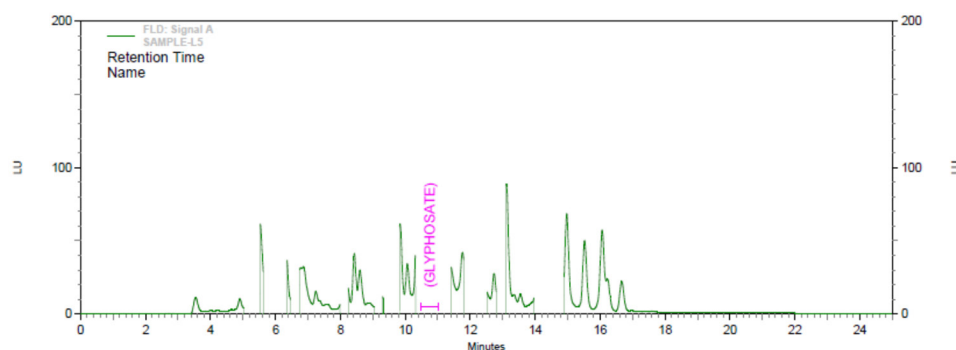


Fig. 20. UHPLC Curve in sample.

tested samples by UHPLC (Fig. 20)

DISCUSSION

The present study demonstrates that chronic exposure to glyphosate exerts significant adverse effects on growth performance and multiple organ systems in kuroiler birds. The marked reduction in body weight gain observed in Group II birds can be primarily attributed to the toxic impact of glyphosate on the gastrointestinal tract. This toxicity likely induces diarrhoeal conditions and compromises intestinal integrity resulting in impaired digestion and nutrient absorption. Such findings are consistent with earlier reports that identify reduced growth performance as a key indicator of systemic toxicity following chronic exposure^{13, 14}. The architectural disruption in the spleen is indicative of an immunotoxic response¹⁵. Such alterations are often associated with oxidative stress-mediated damage and can impair normal immune function¹⁶. Similar findings reported in previous studies highlight that toxicants like glyphosate can induce lymphoid depletion and structural disorganization in immune organs, ultimately leading to immune dysregulation^{17, 18}. Furthermore, the gastrointestinal alterations noted in the study may also be linked to glyphosate-induced disruption of the normal gut microbiota¹⁹.

Glyphosate is known to affect microbial populations by inhibiting the shikimate pathway, which is present in many commensal bacteria. The pancreatic lesions are attributed to the affect in mRNA expression of some enzymes such as Interleukin 6 (IL) in pancreatic tissue²⁰.

This disruption can lead to intestinal dysbiosis, further exacerbating nutrient malabsorption and contributing to the overall decline in health status. Brain lesion observed in the present study, including congestion, cytoplasmic vacuolation and neuronophagia, suggest substantial neuronal injury. These changes may be mediated through excitotoxic mechanisms and the generation of reactive oxygen species leading to oxidative stress and mitochondrial dysfunction causing neuronal degeneration²¹. The ability of glyphosate and its metabolites to induce oxidative damage in neural tissues has been increasingly recognized, thereby supporting the observed histopathological findings²². An important aspect of glyphosate toxicokinetics is its rapid biotransformation into metabolites such as amino methyl phosphonic acid (AMPA), which are themselves biologically active and contribute to overall toxicity. Thus, the absence or low detection of the parent compound in tissues does not preclude toxic effects, as these may be mediated by its metabolites and associated co-formulants.

In contrast, birds in Group III supplemented with ashwagandha powder showed significant improvement in growth performance along with the absence of notable histopathological lesions. This indicates a protective and ameliorative role of the plant. The beneficial effects of Ashwagandha can be attributed to its well-documented adaptogenic, antioxidant and anabolic properties. These properties enhance the physiological resilience of the host, mitigate oxidative stress and help maintain cellular integrity under toxic conditions^{23, 24}.

CONCLUSION

Chronic glyphosate exposure induces significant systemic toxicity in kuroiler birds, as evidenced by impaired growth performance and multisystemic pathological alterations. The findings also highlight the need for comprehensive evaluation of the toxic contributions of glyphosate metabolites, as well as formulation adjuvants and surfactants, which may exacerbate overall toxicity. Dietary supplementation with ashwagandha powder demonstrated a pronounced protective effect by mitigating toxic insults, preserving tissue integrity and improving physiological performance. These results underscore its potential as a phytogenic adaptogen for alleviating herbicide-induced stress and enhancing productivity in poultry under conditions of agrochemical exposure. Further investigations are warranted to elucidate the precise molecular mechanisms underlying its protective actions and to establish optimal dosage regimens for effective field-level application.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support provided by the Authority of the College of Veterinary Science (CVS), Khanapara, Assam Agricultural University (AAU) for carrying out this research work. The authors are also thankful to the Dean and the Director of Post Graduate Studies (DPGS), HOD, Department of Pathology, College of Veterinary Science, Khanapara, for their administrative support and encouragement. The authors sincerely express their deep sense of gratitude to Dr. T. N. Upadhyay for his invaluable guidance and constant support. The authors further acknowledge the valuable suggestions and cooperation extended by Dr. D. C. Pathak, Dr. S. Sarma, and Dr. G. C. Roy during the course of the study.

Financial support & sponsorship: None

Conflicts of Interest: None

Use of Artificial Intelligence (AI)-Assisted Technology for manuscript preparation: The authors confirm that there was no use of AI-assisted technology for assisting in the writing of the manuscript and no images were manipulated using AI.

REFERENCES

- Brookes G. 2025. Glyphosate use in agricultural products: Its contribution in global carbon di oxide emission. *GM Crops Food* 17(11): 2594217
- Benbrook CM. 2024. Trends in glyphosate herbicide use and its implications in human and environmental health. *Environmental Sciences Europe* 36 (1): 45-60.
- Pal A, Mahadeva N, Farhath K, Bawa AS. 2012. In-vitro studies on the antioxidant assay profiling of root of *Withaniasomnifera*. (Ashwagandha) Dunal. *Agriculturae Conspectus Scientificus* 77: 95-101
- Jediya H, Joshi M, Sharma SK. 2026. Effect of Phytobiotic Feed Additives- Garlic (*Allium sativum*), Ashwagandha (*Withaniasomnifera*) and Shatavari (*Asparagus racemosus*) as Alternatives to Antibiotic on Growth Performance and Economics in Broiler Chicken. *Agricultural Science Digest* 10.18805/ag. D-6403.
- Bhargavan D, Deepa B, Shetty H, Krishna AP. 2017. The protective effect of *Withaniasomnifera* against oxidative damage caused by ethanol in the testes of adult male rats. *International Journal of Basic & Clinical Pharmacology* 4(6): 104-1108.
- Kalaiselvan K, Sweatha V, Gayathri V, Kalaivani P, Siva R, Tamrakar S. 2025. Reproductive and developmental safety assessment of Ashwagandha (*Withaniasomnifera*) root extract in Wistar rats. *Front Pharmacol* 16:1572025.
- OECD. 2008. Test No. 425: Acute Oral Toxicity: Up-and-Down Procedure, OECD Guidelines for the Testing of Chemicals, Section 4. OECD Publishing, Paris.
- Deora PS, Mishra CK, Mavani P, Asha R and Shrivastava B, Rajesh KN. 2010. Effective alternative methods of LD50 help to save number of experimental animals. *J. Chem. Pharm. Res* 2(6):450-453
- Bishnoi N. 2015. Studies on effect of Ashwagandha (*Withaniasomnifera*) on chlorpyrifos toxicity in broiler chicks. Department of Veterinary Pathology, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hissar.
- Luna LG. 1968. Manual of Histologic staining methods of the Armed Forces Institute of Pathology. 3rd Edition, McGraw-Hill, Toronto, London, Sydney.
- Sharma OP, Pholphana N, Rangkadilok N, Parkian P, Satayavivad J. 2015. Development of simple and sensitive HPLC method and determination of Glyphosate residues in Soybean. *Nep Environ Sci* 3: 21-26.
- Snedecor GW, Cochran WG. 1994. Statistical Methods. 6th ed., Oxford and IBH Publishing Company, New Delhi.
- Seralini GE, Mesnage R, Gress S, Defarge N, Malatesta M, Hennequin D, de Vendomois JS. 2014. Republished study: long term toxicity of a Roundup herbicide and a Roundup tolerant genetically modified maize. *Env Sci Europe* 26:14.
- Strilbyska OM, Tsiumpala SA, Kozachyshyn II, Strutynska T, Burdyliuk N, Lushchak VI, Lushchak O. 2022. The effects of low-toxic herbicide Roundup and glyphosate on mitochondria. *EXCLI J* 21:183-196.
- Ishola OA, Ajao AA, Adewoye SO. 2026. Histopathological Evidence of Liver and Spleen Alterations Following Sub-Chronic Glyphosate Exposure in Wistar Rats. *Direct Research Journal of Public Health and Environmental* 11(1): 53-57.
- Calmday OD, Oghosa AJ, Imafidon EO, Popoola SO, Innih S. 2026. Anatomical Investigation of Glyphosate-Induced Toxicity on the Spleen of Adult Wistar Rats. *Journal of Applied Sciences and Environmental Management* 29(12): 3739-3746.
- Turkmen R, Yildirim S, Kaya H. 2025. Immunotoxin and oxidative effects of glyphosate on splenic tissue in experimental rats. *Environmental Research* 240: 117389.
- Adebayo IO, Ajao AA, Adewoye SO. 2025. Histopathological and immunotoxin effects of sub-chronic glyphosate exposure in Wistar rats. *Journal of Environmental Toxicology and Public Health* 18(2): 115-126.
- Ignacio ADC, Guerra AMDR, de Souza-Silva TG, Carmo MAVD, Paula HAA. 2024. Effects of glyphosate exposure on intestinal microbiota, metabolism and microstructure: a systematic review. *Food Funct* 15(15):7757-7781.
- Laptev GY, Tiurina DG, Yildirim EA, Filippova VA, Dubrovin AV, Duvrovina AS et al. 2025. Effects of Glyphosate, antibiotics and an anticoccidial drug on pancreatic gene expression and blood physiology in broilers. *J Zhejiang Uni Sci B* 26(2): 185-199.
- Mazuryk J, Klepacka K, Kutner W, Sharma PS. 2024. Gly-

- phosate: Impact on the microbiota-gut-brain axis and the immune-nervous system, and clinical cases of multiorgan toxicity. *Ecotoxicol Environ Saf* 271:115965.
22. Chavez-Reyes J, Gutierrez-Reyes CD, Hernandez-Cuellar E, Marichal-Cancino BA. 2024. Neurotoxicity of glyphosate: focus on molecular mechanisms probably associated with alterations in cognition and behavior. *Environ Toxicol Pharmacol* 106:104381.
 23. Vasanthkumar P, Pangayarselvi B, Sasikumar P, Chandrasekaran D, Doraisamy KA, Purushothaman MR. 2015. Performance of broilers fed Ashwagandha (*Withania somnifera*) incorporated diets during summer season for alleviating heat stress. *Indian J Anim Res* B-2646: 1-3.
 24. Mitra S, Munni YA, Dash R, Sultana A, Moon IS .2022. Unveiling the effect of *Withania somnifera* on neuronal cytoarchitecture and synaptogenesis: a combined in vitro and network pharmacology approach. *Phytother Res* 36:2524-41.