

National University of Life
and Environmental Sciences of Ukraine

**UKRAINIAN JOURNAL
OF VETERINARY SCIENCES**

Vol. 17, No. 2

Kyiv
2026

Publisher:

National University of Life and Environmental Sciences of Ukraine

Year of foundation: 2010

*Recommended for printing and distribution
via the Internet by the Academic Council
of National University of Life and Environmental Sciences of Ukraine
(Minutes No. 13 of May 21, 2026)*

**Decision of the National Council
of Television and Radio Broadcasting of Ukraine No. 1795,**
Minutes No. 31, dated 21.12.2023.
Media identifier - R30-02299.

The journal is included in the list of professional publications of Ukraine

Category "B". Field of Science: Veterinary Sciences.
Cluster: Agricultural and Veterinary Sciences.
Specialty: 0841 – Veterinary
(Order of the Ministry of Education and Science of Ukraine
No. 1693 dated December 23, 2025)

**The journal is presented international scientometric databases, repositories
and scientific systems:** DOAJ, Google Scholar, Vernadsky National Library of Ukraine, BASE,
CAB Abstracts and Global Health (CABI), Polska Bibliografia Naukowa (PBN), Ulrichsweb,
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Національний університет біоресурсів
і природокористування України

**УКРАЇНСЬКИЙ ЧАСОПИС
ВЕТЕРИНАРНИХ НАУК**

Том 17, № 2

Київ
2026

Видавець:

Національний університет біоресурсів і природокористування України

Рік заснування: 2010

*Рекомендовано до друку та поширення
через мережу Інтернет Вченою радою
Національного університету біоресурсів і природокористування України
(протокол № 13 від 21 травня 2026 р.)*

**Рішення Національної ради України
з питань телебачення і радіомовлення № 1795,
протокол № 31 від 21.12.2023 р.
Ідентифікатор медіа - R30-02299.**

Журнал входить до переліку наукових фахових видань України

Категорія «Б». Галузь наук – Ветеринарні.
Кластер: сільськогосподарські і ветеринарні науки.
Спеціальність Н6 (211) - Ветеринарна медицина
(Наказ Міністерства освіти і науки України № 1693 від 23 грудня 2025 р.)

**Журнал представлено у міжнародних наукометричних базах даних,
репозитаріях та пошукових системах:** DOAJ, Google Scholar, Національна бібліотека
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Фахові видання України, EBSCO, Litmaps

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03041, вул. Героїв Оборони, 15, м. Київ, Україна
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Methods for collecting ixodid ticks to control the spread of vector-borne diseases in domestic dogs

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Abstract. The issue of selecting methods for collecting ticks, particularly ixodid ticks, has become important for controlling the spread of vector-borne diseases in domestic dogs, which may carry ticks on their coats into their owners' homes and pose a risk of transmitting Lyme borreliosis to humans. The aim of the study was to analyse tick collection methods and substantiate their advantages and limitations. The research included analytical-observational, theoretical-modelling, and generalisation-implementation stages. During the analytical-observational stage, it was established that the principal tick collection methods were Dragging, Flagging, CO₂ traps (dry ice/baited traps), Host Examination, and Absolute Surface Counts. At the theoretical-modelling stage, the feasibility of using these methods was justified and the most effective approaches were identified. The study determined the methods that were more suitable for use in Ukraine, as they provided an optimal combination of accessibility, reproducibility, and epizootiological informativeness, while also enabling the acquisition of both quantitative and qualitative indicators concerning population density, species composition, and the intensity of ixodid tick infestation. During the generalisation-implementation stage, two tick collection methods were selected that were convenient to use and required lower material costs. In the course of the practical component of the study, 840 ticks were collected from the Polissia region using these methods, indicating potential risks for the spread of vector-borne diseases. In total, 87 dogs were examined, of which 56 had previously been treated with acaricidal preparations based on pyrethroids and isoxazolines. Dogs of various breeds, aged from 9 months to 12 years, kept under different conditions at the selected research locations, were examined. The study established that the role of domestic dogs as reservoirs of vector-borne infections and mechanical

Suggested Citation:

Kravchuk, O. (2026). Methods for collecting ixodid ticks to control the spread of vector-borne diseases in domestic dogs. *Ukrainian Journal of Veterinary Sciences*, 17(2), 11-25. doi: 10.31548/veterinary2.2026.11.

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carriers of ixodid ticks is a more effective method for monitoring the spread of tick populations in urban areas than field collection methods such as Dragging

Keywords: vector-borne infections; Lyme borreliosis; acarological monitoring; ectoparasites; veterinary parasitology

Introduction

Ixodid ticks (*Ixodidae*) are one of the two principal families of parasitic ticks belonging to the order *Ixodida* (subclass *Acari*, class *Arachnida*). They are responsible for a number of vector-borne diseases in dogs, including anaplasmosis, babesiosis, borreliosis, and rickettsioses. At the same time, domestic dogs may act as a risk factor for human infection, as they are capable of mechanically carrying ticks on their coats, introducing them into residential premises and thereby creating a potential hazard for owners. O. Kravchuk (2025) noted that one of the key preventive measures against Lyme disease was the regular monitoring of tick abundance in natural biotopes, particularly in regions of high tick activity. Monitoring tick populations in different biotopes has become an important component in the prevention of vector-borne diseases, especially Lyme disease. Regular epidemiological studies concerning tick population density have enabled the assessment of pathogen transmission risks and the timely implementation of preventive measures. W. Buczek *et al.* (2024), while analysing the distribution of ixodid ticks in eastern Poland, documented the first confirmed human infestation by *Dermacentor reticulatus*, which had been partially engorged with blood and introduced into a household by a dog.

During investigations of *Ehrlichia canis* (an intracellular bacterium causing canine monocytic ehrlichiosis and transmitted predominantly by *Rhipicephalus sanguineus sensu lato* – the brown dog tick), G. Sgroi *et al.* (2024) documented a confirmed case of human infection

originating from a tick brought into a residence by a dog. In the province of Quebec (Canada), L. Duplaix *et al.* (2021) analysed infestations of dogs and cats by *Ixodes scapularis* and the spread of vector-borne pathogens among domestic animals during 2010–2018, concluding that companion animals had become important “bioindicators” of zoonotic risk to humans. During a study of canine behaviour in north-western Mexico and border regions of the United States, J. Foley *et al.* (2024) identified domestic factors contributing to household tick infestations and the occurrence of vector-borne diseases in humans associated with dogs. The authors also documented outbreaks of RMSF (Rocky Mountain spotted fever) associated with the brown dog tick (*Rhipicephalus sanguineus*). T. Do *et al.* (2024) confirmed that *R. sanguineus* in Vietnam actively transmits zoonotic pathogens, including those capable of infecting humans. The researchers established that domestic dogs serve as a crucial “bridge” between ticks and humans. J. Probst *et al.* (2023) conducted a national-level study in Germany and Austria concerning the risks of tick exposure, particularly *Ixodes ricinus* and *Dermacentor reticulatus*, in domestic animals (dogs and cats) in the context of climate change, range expansion, and associated risks over a 14-month period (March 2020 – October 2021) involving 219 veterinary practices. The study demonstrated that the risk of tick-borne infection in companion animals was not restricted to the “spring-autumn” season.

Ixodes ricinus inhabits many regions of Ukraine, adapting to changing environmental

conditions through variations in idiosoma size, diapause mechanisms, and the ability to parasitise both mammals and birds. The species is well adapted to urban environments, particularly within settlement agglomerations (Panteleienko *et al.*, 2022). R. Cuadrado-Matías *et al.* (2023) investigated the effectiveness of various collection methods for ixodid ticks of the species *Hyalomma lusitanicum*, an important vector of Crimean-Congo haemorrhagic fever virus. Domestic dogs were shown to play a particular role as passive carriers of ticks into households, confirming the importance of systematic monitoring of tick populations both in the environment and on animals themselves in order to rapidly detect changes in species density and adjust preventive measures accordingly. The studies demonstrated that the selection of collection methods significantly influences the assessment of actual tick density and the evaluation of infection risks in dogs. The aim of this article was to analyse the principal methods for collecting ixodid ticks for the control of vector-borne diseases in domestic dogs and to substantiate the most effective approaches to their implementation while considering ecological, epizootiological, and socio-domestic factors.

Literature Review

There are numerous scientific studies comparing methods for collecting ticks to control the spread of vector-borne diseases in humans and animals. Given the variety of methods for collecting Ixodidae ticks, the dragging method has emerged as the simplest to use and the least costly, according to researchers. S. Sadangi *et al.* (2025) used the dragging method to assess urban green spaces as natural habitats for *Ixodes ricinus* ticks. The application of this method enabled the researchers to obtain a representative number of ticks of various developmental stages and sexes, which allowed to assess population density and the intensity

of infestation in the study areas, as well as to conduct laboratory studies to identify the pathogens of tick-borne infections. S.J. England *et al.* (2023) conducted a study on the effect of an electric field on the attraction of ticks to hosts. The scientists demonstrated that electrostatic forces can passively attract ticks to an animal's body, which increased the efficiency of their attachment and could influence the spread of vector-borne diseases. Thus, the Dragging and Flagging methods may be sufficiently effective, as dragging a flag through vegetation promoted the accumulation of a static charge that attracted ticks. N. Boulanger *et al.* (2024) noted that the Dragging field method has become one of the most common ways of capturing ticks that were in a host-seeking (questing) state. After collection, the researchers identified the ticks to species (predominantly *Ixodes ricinus*), froze the samples ($\approx -20^{\circ}\text{C}$) and performed molecular analysis (PCR, qPCR) to detect pathogens, in particular *Borrelia burgdorferi* and *Anaplasma phagocytophilum*.

The authors P. Briggs *et al.* (2025) tested the effectiveness of two tick collection methods, namely Dragging – the authors used a white cloth (100% cotton, $\sim 1\text{ m}^2$), stretched over a wooden pole, with ropes at the ends to control the cloth. The researchers dragged it across grass and leaf litter, periodically checking it for ticks and removing them with tweezers into laboratory test tubes. The CO_2 trap method involved using $\sim 1.4\text{ kg}$ of dry ice placed in a polystyrene container with CO_2 outlet holes, which was positioned above a $\sim 1\text{ m}^2$ canvas fitted with double-sided adhesive tape around its edges to trap ticks crawling towards the CO_2 (the trapping duration ranged from 115 to 168 minutes). The researchers concluded that the dragging method is more suitable for collecting nymphs, whilst the CO_2 trap method is better for collecting adult mites. In their study, C.A. Wheeler *et al.* (2026) collected 25,596 ticks during the

spring and summer of 2023 in Texas, Oklahoma and Wisconsin, and confirmed the superiority of CO₂ traps over the standardised CDC method – fabric dragging and flagging. Scientists T. Koser *et al.* (2025) compared the dragging method with the method of surveying an area using a scent-detection dog. The aim of their experiment was to assess whether dogs trained in scent detection could detect *D. albipictus* in natural conditions, and whether they could do so more accurately or quickly than traditional methods such as Tick Dragging and Flagging. The researchers concluded that detection dogs can be effectively used in tick monitoring programmes, particularly in hard-to-reach landscapes or where population density is low; furthermore, they are capable of detecting individual ticks or small clusters, which are virtually impossible to find using the dragging method. K.M. Holcomb *et al.* (2023) analysed two tick collection methods: active – standard dragging of a cloth through vegetation to collect ticks seeking a host; passive – voluntary submission of ticks by the state's population to a research station for free identification and testing for pathogens. The researchers noted that both methods were sufficiently effective: passive surveillance could serve as the first level of screening, whilst active surveillance could be used where a quantitative risk assessment is required.

J. de la Fuente *et al.* (2023) also highlighted the role of two methodological approaches: active surveillance through flag/drag sampling and passive surveillance through citizen science initiatives and The Tick App, a mobile application in which users independently register detected ticks. P.R. Harman *et al.* (2024) conducted active tick monitoring across 45 sites in four counties of the United States – Hidalgo, Doña Ana, Otero, and Eddy. The authors analysed active collection methods involving dragging flannel cloths (1.2×1.2 m) and stationary CO₂ traps; however, these methods

failed to yield any tick specimens. Passive tick collection involved collaboration with veterinary clinics, dog day-care centres, animal shelters, and farmers who removed ticks from live animals during routine care procedures. Through this approach, 497 ticks representing five identified species were collected from three species of domestic mammals and six species of wild mammals for further investigation. M.E. Tsoumani *et al.* (2023) proposed the prediction of tick distribution, including vector-borne diseases, through the application of climatic models. The authors concluded that climate change has become a major factor influencing the dynamics of tick-borne diseases in Europe. Rising temperatures and changing weather conditions may lead to increased tick abundance, expansion of their geographical range, and higher disease incidence among human populations. In this regard, the use of climatic models and the development of preventive strategies have become essential for reducing future risks. C.H. Wilson *et al.* (2022), during a nationwide monitoring survey involving dogs and their owners, demonstrated that monitoring ticks through direct collection from animals became a key component of epidemiological surveillance systems targeting *Ixodes scapularis*, *Ixodes pacificus*, and their associated pathogens. Thus, the principal methods of tick collection may be identified as Dragging, Flagging, CO₂ traps (dry ice/baited traps), Host Examination, Absolute Surface Counts (ASC), and Scent Detection Dogs.

Materials and Methods

To achieve the stated aim, a comprehensive methodological approach was applied, combining an analysis of scientific literature published between 2021 and 2025, a comparative evaluation of tick collection methods, and the systematisation of data concerning ecological, epizootiological, and socio-domestic

determinants of the risk of vector-borne diseases in domestic dogs. The principal stages of the study included: the analytical-observational stage, which involved analysis of Ukrainian and international experience concerning tick collection methods and was based on the review of scientific publications; the theoretical-modelling stage, which encompassed the substantiation of tick collection methods and the stepwise organisation of the process, including the selection of the optimal period for fieldwork according to seasonal tick activity, preparation of the necessary equipment and materials, direct collection of ticks within natural environments, and their subsequent fixation, labelling, and transportation to the laboratory for further analysis; and the generalisation-implementation stage, which enabled confirmation of the effectiveness of the selected methods. Two methods were selected for tick collection during the study: Dragging and direct collection of ticks from animals. The Dragging method was conducted within selected territories of the Polissia zone during the spring-summer period (May-June) of 2024-2025. In total, 840 ixodid ticks were collected from natural biotopes, including specimens

removed from vegetation and from animals within the selected settlements (Fig. 1).

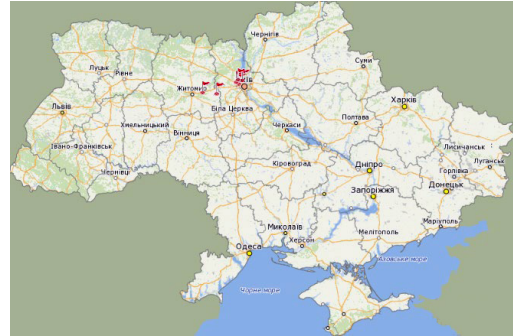


Figure 1. Territories for the collection of ixodid ticks in Kyiv and Zhytomyr regions (marked with red flags)

Source: Meta. Maps of Ukraine (n.d.)

Within Kyiv region, the Obolonskyi district (Pushcha-Vodytsia), Brovary district (village of Semypolky), Bucha district (city of Bucha, village of Kotsiubynske), and Vyshhorod district (village of Dymer) were selected, where a total of 281 ixodid tick specimens were collected. Within the city of Kyiv, the territory of Trukhaniv Island was investigated. In Zhytomyr region (city of Korostyshiv, village of Brusyliv), a total of 187 specimens were collected (Table 1).

Table 1. Total number of ixodid ticks collected in 8 settlements of Kyiv and Zhytomyr regions per 100 m² of territory

Name of settlement	<i>Ixodes ricinus</i>		<i>Dermacentor reticulatus</i>		Number of collected ticks
	Males	Females	Males	Females	
Pushcha-Vodytsia (Obolonskyi district)	9	10	17	24	60
Trukhaniv Island (Kyiv)	9	10	11	21	51
Kotsiubynske village (Bucha district)	10	15	7	14	46
Korostyshiv (Zhytomyr region)	13	23	21	33	90
Bucha	5	3	8	17	33
Brusyliv village (Zhytomyr region)	10	22	25	40	97
Dymer village	7	13	9	16	45
Semypolky village (Brovary district)	5	12	10	19	46
Total					468

Source: compiled by the authors

The comparison of the effectiveness of the Dragging method and the direct collection of ticks from animals had certain limitations due to their differing nature. Within the selected territories, a white cloth measuring 1 m² was deployed and dragged across grassy and shrub vegetation over a distance of 100 m. Nymphal and adult ticks attaching to the material were collected using forceps and placed into Eppendorf tubes. Proper storage of ticks was considered important, as inappropriate conditions could result in degradation of genetic material. In general, studies of this type commonly employ such storage methods as preservation in alcohol, frozen storage, or storage in specialised RNA-preserving buffers (Krupa *et al.*, 2024). Two methods for preserving ixodid tick specimens were selected for the present study. The first method involved storing the material in Eppendorf tubes containing 90% ethanol. Prepared Eppendorf tubes contained between 8 and 10 specimens for subsequent analysis of species composition within the selected territories (Fig. 2).



Figure 2. Example of tick storage from selected areas

Source: photo by the author

The second method (dry) involved freezing the collected specimens in dry Eppendorf tubes at a temperature of -18°C. Parasites preserved using the second method were subsequently submitted for diagnostic testing aimed at monitoring the spread of vector-borne diseases. Since storage in ethanol may inhibit subsequent DNA amplification by polymerase chain

reaction (PCR), ticks stored in dry Eppendorf tubes at -18°C were selected for the study. The investigation involving direct collection of ixodid ticks from dogs was conducted using patients of the veterinary clinic “Innovet”. In total, 87 dogs of different breeds and sexes, aged from 1 to 9 years, kept under various housing conditions (indoor housing and outdoor yard housing), were examined. During history collection from the owners at the time of veterinary examination, a survey was conducted. Owners provided consent for examination of the animals and supplied information concerning the use of acaricidal treatments. A number of questions were asked in order to obtain the necessary information, including the age of the dog (breed was not considered within the study), whether the animal had outdoor access, whether it had been treated with acaricidal preparations, whether previous tick infestations had been recorded, as well as weighing of each examined animal, assessment of mucous membranes, and thermometry. Tick identification was performed using morphological characteristics (magnifying lens and light microscopy), as funding for genetic testing of ticks was not available. The study was conducted in accordance with ARRIVE requirements (n.d.). The density of ixodid ticks was assessed using the ASC method by calculating the number of specimens per unit area (individuals/m²) as the ratio between the total number of collected specimens and the area of the surveyed territory:

$$\text{Density (ticks/m}^2\text{)} = \frac{\text{Total number of ticks collected}}{\text{Total area (m}^2\text{)}}. \quad (1)$$

The results of the study were analysed using Pearson’s statistical method, according to the formula:

$$\chi^2 = \sum \frac{(O-E)^2}{E}, \quad (2)$$

where *O* – observed value, *E* – expected value.

Results and Discussion

The process of collecting ticks in different types of landscapes (woodlands, open meadows, mixed ecosystems) showed that landscape characteristics had a significant impact on the abundance and distribution of *Ixodes ricinus*. To reduce the risk of tick-borne infections, it is recommended that landscape types be taken into account when planning preventive measures; studies of tick abundance should consider the interactions between landscape, climate change and tick biology to generate more accurate predictions of their population dynamics. With this in mind, sites were selected that allowed for an adequate assessment of tick presence. The study results indicated the prevalence of two species of ixodid ticks – *I. ricinus* and *D. reticulatus* – with their distribution varying depending on the natural habitat, host animals and region. In total, 700 m² were surveyed (100 m² covered in each zone), encompassing seven sites within the Polissia region. To assess the population density of ixodid ticks per 1 m², the ASC calculation method was selected, using which the ticks collected with a 1×1 m² gauze sheet from

the soil surface and vegetation within a clearly defined area were counted. The selected area was dominated by grassland vegetation, namely: weed (segetal) vegetation, clover and mixed grasses. Unlike traditional methods – dragging (dragging a cloth), flagging (flag method), and CO₂ traps – the ASC method was used for direct observation of the mite population in a specific area. This method was developed specifically to determine the behavioural characteristics of ticks in accordance with the ecological conditions of the areas: adult ticks actively moved across open surfaces and often concentrated locally in areas of host activity. To obtain results analysing the population density of ixodid ticks in selected areas of the Polissia region, the collected ticks were counted and a morphological identification of the species composition of the parasites was carried out. For each animal, the number of ticks removed and the chosen product for further protection against ectoparasites were recorded. The individual characteristics of the animals, their housing conditions, the number of ticks detected and the recommended products are presented in Table 2.

Table 2. Dogs treated with acaricidal preparations and the number of ticks removed from them

No.	Dogs (breed, age)	Housing conditions	Number of ticks removed	Preparations of choice
1	Crossbreed, 5 years	Indoor	2	Sarolaner
2	English Toy Terrier, 2 years	Indoor	3	Fluralaner
3	Miniature Pinscher, 4 years	Country house	4	Sarolaner
4	Labrador Retriever, 7 years	Indoor with walks in wooded areas	2	Lotilaner
5	Shiba Inu, 3 years	Indoor	2	Afoxolaner
6	Crossbreed, 5 years	Rural housing	2	Sarolaner
7	Crossbreed, 3 years	Indoor with walks in fields	3	Fluralaner
8	Belgian Griffon, 3 years	Rural housing	4	Lotilaner
9	Weimaraner, 9 years	Indoor	2	Sarolaner
10	Medium German Spitz, 4 years	Indoor	2	Fluralaner
11	Crossbreed, 1 year	Rural housing	4	Fluralaner
12	Crossbreed, 6 years	Indoor with walks in wooded areas	3	Sarolaner
13	Crossbreed, 5 years	Indoor	2	Lotilaner
14	Crossbreed, 7 years	Indoor	3	Permethrin
15	Crossbreed, 2 years	Indoor	3	Afoxolaner
16	Malinois, 3 years	Indoor with walks in wooded areas	2	Sarolaner

Table 2. Continued

No.	Dogs (breed, age)	Housing conditions	Number of ticks removed	Preparations of choice
17	Yorkshire Terrier, 6 years	Indoor	2	Fluralaner
18	Dobermann, 8 years	Kennel housing	2	Fluralaner
19	Spitz, 4 years	Indoor with walks in wooded areas	4	Sarolaner
20	Crossbreed, 9 years	Indoor with walks in wooded areas	3	Sarolaner
21	Maltipoo, 4 years	Indoor	2	Lotilaner
22	Maltipoo, 6 years	Indoor	2	Permethrin
23	Yorkshire Terrier, 9 years	Indoor with walks in wooded areas	2	Afoxolaner
24	Yorkshire Terrier, 7 years	Rural housing	3	Sarolaner
25	Husky, 8 years	Indoor with walks in wooded areas	2	Fluralaner
26	Crossbreed, 8 years	Indoor	4	Afoxolaner
27	Akita Inu, 4 years	Indoor	3	Fluralaner
28	Crossbreed, 3 years	Indoor with walks in wooded areas	2	Fluralaner
29	Malinois, 2 years	Indoor	4	Lotilaner
30	Central Asian Shepherd Dog, 8 years	Indoor with walks in wooded areas	2	Sarolaner
31	Spitz, 4 years	Indoor	3	Sarolaner
32	Spitz, 7 years	Indoor with walks in wooded areas	3	Sarolaner
33	Crossbreed, 3 years	Indoor	2	Fluralaner
34	Crossbreed, 2 years	Indoor	4	Fluralaner
35	Jack Russell Terrier, 4 years	Indoor	2	Lotilaner
36	German Shepherd, 9 years	Kennel housing	2	Permethrin
37	Hungarian Short-Haired Vizsla, 5 years	Outdoor yard housing	3	Afoxolaner
38	Maltipoo, 4 years	Indoor	4	Sarolaner
39	English Cocker Spaniel, 3 years	Outdoor yard housing	2	Sarolaner
40	Pug, 7 years	Indoor	2	Sarolaner
41	Boston Terrier, 4 years	Indoor with walks in wooded areas	2	Fluralaner
42	Italian Cane Corso, 6 years	Indoor with walks in wooded areas	3	Fluralaner
43	Crossbreed, 3 years	Indoor	2	Fluralaner
44	Crossbreed, 6 years	Indoor with walks in wooded areas	2	Lotilaner
45	Crossbreed, 2 years	Indoor	2	Permethrin
46	Tibetan Spaniel, 5 years	Indoor	2	Afoxolaner
47	Kurzhaar, 4 years	Outdoor yard housing	3	Fluralaner
48	Crossbreed, 3 years	Indoor	3	Permethrin
49	Yorkshire Terrier, 4 years	Indoor	2	Sarolaner
50	Bichon Frise, 5 years	Indoor with walks in wooded areas	2	Sarolaner
51	Malinois, 4 years	Kennel housing	1	Sarolaner
52	Crossbreed, 5 years	Outdoor yard housing	4	Sarolaner
53	Pug, 3 years	Indoor with walks in wooded areas	4	Fluralaner
54	Rottweiler, 6 years	Kennel housing	2	Fluralaner
55	Crossbreed, 7 years	Indoor	2	Lotilaner
56	Belgian Griffon, 5 years	Indoor	3	Afoxolaner

Source: compiled by the author

Thus, it was determined that 56 dogs had previously been treated with acaricidal preparations and had additional protection in the form of collars. The dogs were kept under

different housing conditions, including indoor housing with walks in urban parks and outdoor yard housing with walks in field areas. During interviews with the owners, information was obtained regarding the most commonly used preparations, particularly that they were administered in tablet form and used once monthly or once every three months. The results for tick density saturation within the selected territory according to the ASC method were as follows:

$$\frac{468}{700(\text{m}^2)} \approx 0.67.$$

The value of 0.67 indicated a low density of ixodid tick distribution within the investigated sites, suggesting a reduced risk of parasite attacks and transmission of vector-borne infections during the spring-summer period of 2024-2025. This may have been associated with climatic conditions, as the temperature regimes were unfavourable for the reproduction of ixodid ticks. Additional protective measures were used by animal owners only during walks in wooded areas. It was established that 31 dogs had not received treatments against ectoparasites, although some of the examined dogs had protection in the form of repellent collars (Table 3).

Table 3. List of dogs not treated with acaricidal preparations and the number of ticks removed from them

No.	Dogs (breed, age)	Housing conditions	Number of ticks removed
1	Crossbreed, 7 years	Outdoor yard housing	7
2	Crossbreed, 4 years	Kennel housing	6
3	Crossbreed, 3 years	Free-range housing	9
4	Chihuahua, 10 years	Indoor	8
5	Shih Tzu, 11 years	Found on the street	6
6	German Shepherd, 6 years	Kennel housing	8
7	Crossbreed, 6 years	Outdoor yard housing	8
8	Hungarian Short-Haired Vizsla, 5 years	Kennel housing	6
9	Crossbreed, 4 years	Outdoor yard housing	10
10	Chihuahua, 7 years	Indoor	9
11	Crossbreed, 8 years	Free-range housing	7
12	Boxer, 10 years	Outdoor yard housing	7
13	Crossbreed, 3 years	Outdoor yard housing	8
14	Dalmatian, 6 years	Indoor	8
15	Italian Greyhound, 4 years	Indoor	8
16	Chihuahua, 11 years	Outdoor yard housing	6
17	English Spaniel, 7 years	Outdoor yard housing	5
18	Laika, 5 years	Kennel housing	8
19	Labrador Retriever, 8 years	Indoor	9
20	Labrador Retriever, 2 years	Kennel housing	7
21	Laika, 8 years	Outdoor yard housing	7
22	Crossbreed, 3 years	Indoor	5
23	Crossbreed, 8 years	Free-range housing	10
24	Crossbreed, 5 years	Kennel housing	5
25	Dachshund, 3 years	Indoor	5
26	Chihuahua, 4 years	Indoor	6
27	Crossbreed, 4 years	Outdoor yard housing	7
28	German Shepherd, 4 years	Kennel housing	9

Table 3. Continued

No.	Dogs (breed, age)	Housing conditions	Number of ticks removed
29	Crossbreed, 9 years	Kennel housing	8
30	Crossbreed, 6 years	Indoor	8
31	Labrador Retriever, 3 years	Kennel housing	7

Source: compiled by the author

A total of 372 ticks were collected from the dogs, with between 2 and 4 ticks of the family *Ixodidae* being removed from each dog (Table 4). From animals kept in yard conditions and walked in forested areas (Kyiv and Zhytomyr regions) or in the park zones of Kyiv, between 5 and 10 tick specimens were removed in some cases.

Table 4. Results of the examination of dogs for the presence of ticks

Removed	<i>Ixodes ricinus</i>		<i>Dermacentor reticulatus</i>		Total
	Nymphs	Females	Nymphs	Females	
Treated dogs	29	35	37	45	146
Untreated dogs	54	63	43	66	226
Total					372

Source: compiled by the author

The number of dogs treated (n) = 56, and the number of ticks removed from them = 146; between 2 and 4 ticks were removed from each dog:

$$X = \frac{146}{56} = 2.61,$$

where the mean intensity was 2.61 ticks per animal, with a min-max range of 2-4 ticks; in untreated dogs (n = 31), a total of 226 ticks were removed, with between 5 and 10 ticks being collected from a single dog:

$$X = \frac{226}{31} = 7.29.$$

Thus, the obtained results indicate a high level of effectiveness of acaricidal treatments in dogs. In treated animals, the mean intensity of parasitism was substantially lower, amounting to 2.61 ticks per animal (min-max: 2-4), whereas in untreated dogs this indicator reached 7.29 ticks per animal (min-max: 5-10). Therefore, the use of acaricidal products contributed to a marked reduction in tick infestation levels and a decrease in the parasitic burden on animals. The method for storing and preserving ticks was described in the work by E. Krupa *et al.* (2024), in which the researchers emphasised that after removing ixodid ticks or extracting them from the external environment, they must be preserved for further storage. The study also indicated that material preserved in ethanol (70-97%) can be stored for 10 years without changes to DNA/RNA, which is important for further research into *Ixodidae* ticks and vector-borne diseases. As a result of statistical analysis using Pearson's chi-square test, no significant difference was found in the frequency of tick detection between treated and untreated dogs ($\chi^2 = 2.88$; $P > 0.05$). The distribution of ticks by species (*Ixodes ricinus*, *Dermacentor reticulatus*) and developmental stage (nymphs, females) did not depend on whether acaricidal treatment had been carried out.

The preventive measures applied in the study sample did not demonstrate statistically significant effectiveness in reducing tick numbers. The absence of significant differences was due to the insufficient efficacy of the preparations used; violations of the frequency or technique of treatment; a high level of infestation

pressure in the environment; or an insufficient sample size. The data obtained highlighted the need to improve preventive measures and conduct further research, taking into account

additional risk factors for tick infestation. During the study, a comparison of the effectiveness of the Dragging and Host Examination methods was carried out using Pearson's χ^2 test (Table 5).

Table 5. Comparative effectiveness of the selected methods

Method	Number of ticks	Percentage (%)
Dragging	468	55.7
Host Examination	372	44.3
Total	840	100

Source: compiled by the author

According to Table 5, the dragging method was more productive in terms of the total number of ticks collected, which is due to its ability to cover large areas in a short period of time. At the same time, Host Examination had significantly higher epizootiological value, as it allowed, firstly, to assess the actual level of infestation in animals; secondly, to determine the intensity of parasitism; and thirdly, to directly link the presence of ticks with the risk of pathogen transmission. To test the statistical significance of differences between the number of ticks collected using the selected methods, Pearson's χ^2 test was applied (Egbuchulem, 2024). The total number of ticks collected was 840, of which: 468 were collected using the Dragging method and 372 using the Host Examination method. To assess the effectiveness of the two methods, the total number of ticks detected was conditionally divided equally between the methods, i.e. the expected value for each method was 50% of the total number.

$$E = \frac{840}{2} = 420.$$

Thus, the Expected values are: Dragging – 420, Host Examination – 420. The calculation for the Dragging method was as follows:

$$\frac{(468-420)^2}{420} = \frac{48^2}{420} = \frac{2,304}{420} \approx 5.49.$$

For the Host Examination method:

$$\frac{(372-420)^2}{420} = \frac{(-48)^2}{420} = \frac{2,304}{420} \approx 5.49.$$

Final value:

$$\chi^2 = 5.49 + 5.49 = 10.98 \approx 11.0.$$

Number of degrees of freedom (df) for two categories:

$$df = k - 1 = 2 - 1 = 1.$$

With $df = 1$, the obtained χ^2 value of ≈ 11.0 corresponded to $P < 0.001$, indicating that the differences between the methods were highly statistically significant. Thus, the results of the statistical analysis confirmed that the Dragging method yielded a significantly higher number of collected ticks compared with the Host Examination method, and that the observed difference was not due to chance. The χ^2 (chi-square) value reflected the degree of discrepancy between the observed (actual) and expected (theoretical) frequencies; the df (degrees of freedom) value represents the number of independent parameters that could vary within the statistical model; the p -value indicated the probability that the observed difference arose by chance. The work of A. Springer *et al.* (2026) proved important for the study; they analysed the influence of local landscape characteristics, such as vegetation types, the presence of forests, pastures and water resources, on tick

population dynamics. Furthermore, the researchers identified the factors that most contributed to the survival and activity of *Ixodes ricinus* and analysed seasonal variations in tick abundance depending on local landscapes. S. Zanet *et al.* (2020) demonstrated that clinical examination of dogs and molecular testing of ticks collected from them in Southern Italy enabled the reliable identification of the circulation of *Anaplasma spp.*, *Babesia vogeli* and *Ehrlichia canis* in the region. In Germany, researchers K. Köppen *et al.* (2025) confirmed that systematic Host Examination proved particularly effective in the early detection of *Dermacentor reticulatus* infestations and in assessing the risk of canine babesiosis transmission. V. Levytska & A. Mushynskiy (2020) also confirmed the effectiveness of this approach, demonstrating the value of collecting ticks directly from companion animals in clinical settings as one of the most reliable tools for monitoring the epizootic situation. The researchers demonstrated that regular examinations of dogs and cats enabled the detection of changes in the population structure of *Ixodes ricinus*, *Dermacentor reticulatus* and other species, as well as the recording of seasonal peaks in activity and the frequency of attacks on animals in various biotopes of Western Ukraine. This approach has made it possible not only to assess the actual risk of vector-borne infections, in particular Lyme disease, anaplasmosis and babesiosis, but also to rapidly identify localised areas of increased tick activity.

Conclusions

As a result of the conducted study, the principal methods identified for tick collection were Dragging, Host Examination, and ASC. At the same time, it was important to consider the limitations of these methods. Dragging was effective primarily for collecting ticks in open biotopes; however, its efficiency depended significantly on the type of vegetation cover,

humidity, temperature, and season. Consequently, this method underestimated the actual abundance of ticks present in the soil litter or already parasitising hosts. The Host Examination method provided the most epizootiologically relevant data, although its limitations included dependence on the availability of animals, their behaviour, the regularity of examinations, and the subjective factor of the researcher. The ASC method demonstrated high accuracy only within limited control areas and was poorly suited for large-scale territorial studies due to its labour intensity and time consumption. Thus, the method of collecting ticks directly from dogs is effective provided that the dogs do not receive regular treatment with acaricidal preparations. The Dragging method is also effective, as it enables the acquisition of a comprehensive picture of the spatial distribution of ixodid ticks within natural biotopes. The Dragging method demonstrated greater collection efficiency, accounting for 55.7% of the collected ticks, whereas the Host Examination method yielded 44.3% of the tick specimens. Considering the minor percentage difference, both methods may be regarded as effective. Accordingly, the Dragging and Host Examination methods may be used in combination in studies investigating the species composition of ixodid ticks and the intensity of their populations within particular territories. Prospects for further research include a detailed analysis of additional ixodid tick collection methods within the Polissia zone of Ukraine, with subsequent determination of the species composition and seasonal dynamics of their populations.

Acknowledgements

Gratitude is expressed to the scientific supervisor, Doctor of Veterinary Sciences, Professor N.M. Soroka, for highly professional academic guidance, advice and recommendations, constructive comments, and continuous support throughout all stages of the research.

Professional assistance and scientific mentorship significantly contributed to the development of the study concept, the analysis of the results, and the high-quality preparation of the scientific work.

None.

None.

Funding

Conflict of Interest

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Методи збору іксодових кліщів для контролю розповсюдження трансмісивних хвороб у домашніх собак

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Анотація. Проблема вибору методів збору кліщів, зокрема іксодових, стала важливою для контролю розповсюдження трансмісивних хвороб у домашніх собак, які можуть переносити кліщів на шерсті до осель своїх власників та становити загрозу зараження людини хворобою Лайм-бореліоз. Метою дослідження було здійснення аналізу методів збору кліщів та обґрунтування їх переваг й обмежень. Дослідження охоплювало аналітико-констатувальний, теоретико-моделювальний, узагальнювально-впроваджувальний етапи. Під час аналітико-констатувального етапу було встановлено, що основними методами збору кліщів є Dragging, Flagging, CO2 пастки (dry ice/baited traps), Host Examination, Absolute Surface Counts. На теоретико-моделювальному етапі було обґрунтовано доцільність використання зазначених методів та виокремлено найбільш ефективні. У ході дослідження визначалися методи, які зручніші для застосування на території України, оскільки вони забезпечували оптимальне поєднання доступності, відтворюваності та епізоотологічної інформативності, а також дозволяли отримувати як кількісні, так і якісні показники щодо щільності популяції, видової структури та інтенсивності інвазії іксодових кліщів. На узагальнено-впроваджувальному етапі було обрано два методи збору кліщів, які були зручними у використанні та потребували менших матеріальних затрат. У процесі виконання практичної частини дослідження за допомогою методів було зібрано 840 кліщів з території Полісся, що вказувало на потенційні ризики розповсюдження трансмісивних хвороб. Загалом було обстежено 87 собак, із яких 56 попередньо оброблялись акарицидними препаратами на основі піретроїдів та ізоксозолінів. Обстежувались собаки різних порід, віком від 9 місяців до 12 років, які утримувалися в різних умовах на обраних локаціях для дослідження. У результаті дослідження було з'ясовано, що роль домашніх собак як резервуарів векторних інфекцій та механічних переносників іксодових кліщів є більш ефективним методом для контролю розповсюдження популяції кліщів у міській місцевості, ніж польові методи їх збирання (Dragging)

Ключові слова: векторні інфекції; Лайм-Бореліоз; акарологічний моніторинг; ектопаразити; ветеринарна паразитологія



2026. Volume 17, No. 2 P. 26-42

ISSN 2663-967X;
e-ISSN 2663-9688

Journal homepage: <https://veterinaryscience.com.ua/en>

DOI: 10.31548/veterinary2.2026.26

UDC 619:636.7:616.995.428

Received: 16.01.2026 Revised: 15.04.2026 Accepted: 21.05.2026 Published: 28.05.2026

Parasitic dermatitis in dogs: A literature review of clinical and diagnostic aspects and treatment approaches

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Abstract. Parasitic dermatitis in dogs continues to be one of the most common and clinically relevant problems in modern veterinary practice due to its high incidence and considerable influence on animal health status. This study aimed to summarise current data on the prevalence, aetiology, pathogenesis, clinical manifestations, diagnosis, and treatment of dermatitis of parasitic origin in dogs. The study employed methods of analysis and synthesis of scientific literature sources. Parasitic dermatitis was found to have a polyetiological and multifactorial nature and to be most commonly caused by ectoparasites, particularly fleas, lice, chewing lice, and mites. The leading position in the general structure of the disease was taken by flea allergy dermatitis, and acariases, which are of considerable importance due to their high communicability and propensity for a chronic course, play an important role. Clinical signs were non-specific and manifested as pruritus, erythema, alopecia, crusts and scales, and the development of complications related to the development of secondary bacterial and fungal infection, which complicated the differential diagnosis. Laboratory methods for the detection and identification of pathogens using microscopic, serological and molecular genetic methods proved to be one of the main stages in making a diagnosis. Current treatment methods are based on the use of insectoacaricidal drugs, in particular, isoxazolines and macrocyclic lactones, as well as the control of secondary complications and the implementation of preventive measures. The practical value of this study is the systematisation of

Suggested Citation:

Vovk, M., & Huralska, S. (2026). Parasitic dermatitis in dogs: A literature review of clinical and diagnostic aspects and treatment approaches. *Ukrainian Journal of Veterinary Sciences*, 17(2), 26-42. doi: 10.31548/veterinary2.2026.26.

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current scientific approaches to the diagnosis, treatment and prevention of parasitic dermatitis in dogs in order to improve the efficiency of veterinary practice

Keywords: ectoparasites; allergic skin reactions; pathogenesis; diagnosis; insectoacaricidal therapy; secondary infections

Introduction

Skin parasitic lesions in dogs are still among the most important problems in modern veterinary practice due to the high prevalence, diagnostic problems and their high economic impact on owners and impact on animal health and welfare. The significance of the problem is not only the high incidence of parasitic dermatoses, but also the growing incidence in the conditions of urbanisation, the increase in the number of companion animals and the spread of ectoparasites. A significant point is the risk of infection of other people with some parasites and their potential zoonotic risk, which makes them a significant place among veterinary patients in the concept of One Health.

Currently, the problems of parasitic dermatitis and methods of their analysis are being widely studied, but approaches to determining its prevalence, pathogenesis, and methods of control are different. According to the research of N.G. Agu *et al.* (2020) on the prevalence of ectoparasites among companion animals, flea and mite damage are the most common forms of parasitic lesions, which are associated with animal living conditions, as well as the quality of veterinary care. The leading risk factor for the development of such complications is identified as the lack of systematic preventive actions against parasitic dermatoses.

Dermatitis of parasitic origin was found to be in high numbers among small animal dermatoses in a study on the monitoring of dermatological disease in Ukraine by A.Y. Bogdanova *et al.* (2024). The authors reported the high incidence of allergic parasitic dermatitis,

particularly flea allergy dermatitis, which occurs more often in the presence of high sensitisation of the organism to pathogen antigens. International studies likewise confirm the dominant role of ectoparasites in the structure of dermatological diseases. Specifically, H.A. Zineldar *et al.* (2023) found that the symptoms of parasitic skin infections vary significantly, while the progression of the condition is determined by the parasite species, the degree of infestation, and the animal's immune system. In their opinion, these non-specific clinical signs can make diagnosis more difficult and require laboratory testing to verify results. B.C.F. Nogueira *et al.* (2023) looked at the mechanisms underlying the development of parasitic dermatitis, noting that ectoparasites affect not only the integumentary system but also the homeostasis of the organism as a whole, including haematological indicators and immunity. Thus, they concluded that the pathological process has a systemic character and that a comprehensive approach to treatment is required.

P. Thomson *et al.* (2023) looked at the role of mites in the genesis of dermatopathies in dogs and noted that although acariases, which include sarcoptic mange and demodicosis, are characterised by distinct pathogeneses, they are both characterised by the potential for chronic inflammation and the subsequent development of infections. The authors highlight the importance of distinguishing between different types of dermatitis. M. Ilie *et al.* (2021) outlined the modern approaches to diagnosing parasitic skin diseases, giving specific attention

to molecular-genetic methods. In their analysis, the use of PCR allows one to determine the causative agent more accurately and to differentiate between parasitic dermatitis and other dermatoses. Data published between 2020 and 2025 confirm that the majority of parasitic dermatitis cases were caused by bites from fleas, which resulted in flea allergy dermatitis. Its prevalence can range from 60% to 70% depending on the climatic zone, the effectiveness of preventive measures, and the number of dogs in the population. Veterinary clinics' statistical data indicate that the frequency of parasitic dermatitis in dogs is the greatest among all recorded types of dermatoses, accounting for half of the registered cases (Tadesse *et al.*, 2019).

The dynamics of the prevalence of parasitic diseases are influenced by the geographical and climatic conditions of the area. In general, systematic reviews and meta-analyses showed that in tropical and subtropical countries, a high rate of infestation is typical due to the favourable environmental conditions for the development of the parasites and their vectors, which are high temperatures, high humidity, and a large population of stray animals (Dantas-Torres *et al.*, 2020). In temperate climatic conditions, however, mainly in the northern regions of Europe, the indicators were lower (Baneth *et al.*, 2016). Simultaneously, a marked difference can be noticed even on the territory of Europe: the occurrence of individual types of parasitic infection in Mediterranean countries can be high, while in the central and northern parts – relatively low. In the tropics, in connection with the permanent infection of animals with many types of parasites, the intensity and variety of infestations are higher on average. At the same time, the results of local epizootiological studies reveal significant variation in the occurrence rate even within the borders of individual territories. For example, according to the research of E. Lara-Reyes *et al.* (2021), the occurrence of endoparasites in dogs was 37.2%,

while ectoparasites was 13.1%, which proves the importance of the region and living conditions of the dog on the infestation rate.

In Ukraine, like in many other regions, flea dermatitis accounts for more than half of all reported cases, which highlights the need for preventive activities. This highlights the need for systematic prevention. The spread of parasites and the problem on a global scale is supported by the following factors: the growth of urbanisation, the density of dogs in cities, their migration between regions, and the lack of regular use or lack of antiparasitic drugs at all (Derevianchenko & Petrov, 2023). Also, other ectoparasites of insects and mites can be aetiological agents. Among insects, second in prevalence is the dog chewing louse, among the mites – the causative agents of mange are fairly widespread.

Thus, parasitic dermatitis in dogs is a serious and widespread veterinary disease of global importance, which has a considerable impact on the health of animals. The high prevalence of the disease, different aetiologies of the lesions, a wide range of clinical manifestations, dependence on environmental and social factors, indicate the need for systematic prevention, further diagnostics, and the development of effective treatment for the disease. At the same time, current scientific data on the relationship between the species composition of ectoparasites, the mechanism of the appearance of skin lesions and the variability of clinical manifestations in dogs is not sufficiently systematised, which makes it more difficult to establish timely diagnosis and choice of effective therapy. This scientific gap determined the need for the present study.

This study aimed to systematise and critically analyse current scientific information on the aetiological structure, mechanism of development, clinical course, diagnostic and treatment of parasitic skin lesions in dogs, as well as to identify modern problems and prospects for

improving their prevention in veterinary practice in current conditions. To achieve the stated aim, the following objectives were set: to study scientific literature on the prevalence and aetiology of parasitic skin lesions in dogs, to systematise scientific data on the pathogenesis of the formation of skin parasitic lesions, and to describe the main clinical signs, considering their variability and significance for diagnosing skin parasitic lesions in dogs.

The study was conducted in the form of a narrative review of scientific literature devoted to parasitic dermatitis in dogs. A search for scientific literature was conducted in the databases: Scopus, Web of Science, PubMed, Google Scholar, and ScienceDirect in the time interval 2020-2025. The search utilised keywords and combinations thereof in English and Ukrainian: “parasitic dermatitis in dogs”, “ectoparasites”, “canine demodicosis”, “sarcoptic mange”, “flea allergic dermatitis”, “dog skin parasites”. The review includes peer-reviewed scientific articles, clinical and experimental research, systematic reviews, and some monographs in which the etiopathogenesis, clinical manifestations, diagnosis, and treatment of parasitic dermatitis in dogs are discussed. Conference abstracts, non-peer-reviewed publications, sources of insufficient evidence, duplicate sources, as well as those that did not meet the criteria of the topic and those whose data were no longer relevant were excluded. In the process of the analysis, the information contained in over 130 sources was considered, among which 54 of the most pertinent studies were chosen to form the review as a result of applying the criteria of source selection. The results were processed by the methods of thematic, comparative, and systematic analysis, which made it possible to summarise up-to-date approaches to the study of parasitic dermatitis in dogs and points of contention regarding the interpretation of the mechanisms underlying the

development, diagnosis and treatment of these conditions.

Theoretical foundations and etiopathogenesis of parasitic dermatitis in dogs

The multifactorial nature of parasitic dermatitis should be considered from the standpoint of various fields of science, such as veterinary dermatology, parasitology, and immunology. As noted by J. Miller *et al.* (2023), these conditions result from a complex interaction of parasite and host organism, in which skin barrier status and immune response play a major role. A.Y. Bogdanova *et al.* (2024) also emphasises that parasitic diseases are one of the leading ones in terms of the structure of dermatological diseases in small animals. Consequently, contemporary studies consider parasitic dermatitis not merely as a local skin disorder, but as a systemic process with an immunopathological component. Parasitic dermatitis in dogs belongs to a group of polyetiological diseases with the causative agents of ectoparasites of the phylum Arthropoda Gravenhorst, 1843, and belong to the classes Insecta Linnaeus, 1758 and Arachnida Lamarck, 1801 (subclass Acari Leach, 1817). The greatest veterinary importance among them belongs to insects: fleas and chewing lice, among mites – the causative agents of sarcoptic mange, demodicosis, and otodectic mange. The biological and ecological features of these parasites that influence the mechanism of transmission, the nature of localisation of lesions, the degree of contagiousness and clinical features are the focus of research attention in recent years. A. Prohic (2024) noted that the classification of parasitic dermatitis should take into account not only the parasite species but also the nature of its interaction with the host organism, the duration of parasitism, and the depth of skin involvement. According to current approaches,

parasitic dermatitis is divided into entomoses and acariases. These diseases are categorised based on the taxonomic group of the parasite, the specific area of parasitisation, the nature of the dermatological lesion, and the mechanism of pathogenic activity. Consequently, parasitic dermatitis is considered a large group of diseases that have high economic significance for veterinary practice. They require a systematic approach to diagnosis, treatment, and prevention, and represent one of the main problems of veterinary dermatology today.

According to B.C.F. Nogueira *et al.* (2023), ectoparasites cause harm in dogs due to mechanical action, the development of an allergic reaction, or the occurrence of a favourable condition for secondary microflora. Analysing these mechanisms, H.A. Zineldar *et al.* (2023) emphasised that the nature of disease progression depends on the parasite species, its biological characteristics, and the immune reactivity of the dog's organism. A similar view was expressed by V. Yevstafieva *et al.* (2024), who highlighted the role of sensitisation in the development of chronic forms of the disease. In turn, A.E.C. Cardoso *et al.* (2020) demonstrated that the nature of the inflammatory response is largely determined by the type of exudate and the depth of tissue involvement. Thus, the key pathogenic factor is not merely the presence of the parasite, but also the individual response of the host organism.

Entomoses include dermatitis caused by insects. In dogs, flea allergy dermatitis and trichodectosis are recorded most frequently. Flea allergy dermatitis is a result of the impact of fleas (*Ctenocephalides canis* Curtis, 1826, *C. felis* Bouché, 1835). Flea saliva contains a complex of biological substances that consist of enzymes, anticoagulants, and haptens, which cause both immediate and delayed hypersensitivity in dogs, accompanied by pruritus, erythema, oedema, and excoriations.

With repeated bites, sensitisation increases and causes a chronic process in the disease; the disease progresses with the occurrence of bacterial or fungal infection. This disease is seasonal and is characterised by high activity in summer and autumn, while acariases follows a constant course (Lara-Reyes *et al.*, 2021; Authoy *et al.*, 2023). According to L. Cornegliani *et al.* (2024), a single flea bite can cause a strong manifestation of hypersensitivity, which leads to the development of severe itching and inflammation. The cause of the development of this disease is related to the effect of the parasites' saliva components, antigens, which stimulate the activation of all stages of immune responses. In addition, Y. Ali *et al.* (2020) and Y.T.H. Nguyen *et al.* (2025) drew attention to the role of the neurogenic component in sustaining pruritus, which leads to mechanical damage to the skin. Thus, flea allergy dermatitis represents an example of a pathology in which an immunological mechanism predominates.

Trichodectosis is caused by chewing lice (*Trichodectes canis*, De Geer, 1818), which live permanently on the body of the dog. They feed on epidermal scales and skin secretions. As noted by J. Guillot & R. Bond (2020), the condition is manifested by severe pruritus, hair loss, dryness, and scaling of the skin. At the same time, L.C. Panait *et al.* (2025) emphasised that prolonged parasitism maintains chronic inflammation, which may be complicated by pyoderma and fungal infections. Areas affected by these diseases become a source of unpleasant sensations in the animal and lead to deterioration in the appearance in chronic disease forms. A comparison of these data indicates that, in entomoses, the severity of lesions is determined by the duration of infestation and housing conditions. Acariases are a type of dermatitis caused by mites. They are characterised by high contagiousity, a tendency towards chronicity, and a significant impact on the overall

condition of the animal. Among them are sarcoptic mange, demodicosis, and otodectic mange. Sarcoptic mange is caused by the mite *Sarcoptes scabiei* var. *Canis* Linnaeus, 1758. It burrows tunnels within the stratum corneum of the skin, resulting in intense pruritus, erythema, crust formation, and alopecia. Parasitisation for a long time in an animal is a condition that leads to sensitisation and to the occurrence of a chronic form of the disease. This process often involves secondary microflora infection and aggravates the condition. F. Moog *et al.* (2021) described sarcoptic mange as a contagious disease that is accompanied by a significant increase in pruritus and a rapid spread in animal groups, as well as a high degree of contagiousness of the parasite. In severe cases, it is associated with symptoms of intoxication and general weakness in dogs.

Demodicosis arises from *Demodex* Leydig, 1859 mites, which reside in hair follicles and sebaceous glands. The animals may be carriers of these mites for quite some time, but do not present any clinical signs; only in cases of immunosuppression can the mites cause pathology. The clinical signs of demodicosis are alopecia, scaling, erythema, and itching. The generalised form has a serious clinical course with the development of large areas of skin lesions, secondary infection, and intoxication of the whole organism. Young dogs and certain breeds with a genetic predisposition are particularly susceptible to demodicosis (Gholinezhad *et al.*, 2023; Bhusal *et al.*, 2025).

Otodectic mange is caused by the mite *Otodectes cynotis* Hering, 1838, which parasitises the external auditory canal. A. Melezhyk *et al.* (2024) describe demodicosis as an exudative, pruritic, and inflammatory disease that can involve the tympanic membrane in cases of severe infestation. The highest prevalence of this disease is found in dogs with long ear carriage and dense hair coats. The source of

the infestation is a sick animal, and the path of transmission is direct. As noted by C. Briceño *et al.* (2020), the possibility of direct contact between the animals and the development of contact infestation leads to the rapid spread of the disease within animal populations, so epizootiological measures to prevent the disease are very important.

The occurrence of parasitic dermatitis depends on age, breed of dogs, living conditions, and the degree of veterinary supervision. Young dogs are more likely to develop demodicosis, while dogs with a dense undercoat are more susceptible to chewing lice and other superficial ectoparasites. Factors that increase the likelihood of infestation include crowded housing, lack of preventive actions, and failure to use insectoacaricidal drugs in a timely manner. An increase in the number of ectoparasitoses of dogs is noted in urban areas by S.J. Coates *et al.* (2020) and B. El Hamzaoui *et al.* (2020) due to an increase in the number of animals, an increase in their activity, as well as ongoing urbanisation processes. V. Yevstafieva & K. Horb (2020) noted a strong association between the living conditions of dogs and age-related dynamics of the occurrence of ectoparasites. The study shows that the prevalence of skin lesions in animals kept in apartments was lower than in individuals from the category of the private housing fund. Moreover, for animals in apartments, with an increase in age, the level of infection increases, which may be explained by less careful care and conducting a course of disinfestation specifically aimed at young individuals. However, in the conditions of kennel maintenance, the inverse dynamics is observed – the extent of infection indices and their severity decrease with age, which is due to the activation of the mechanisms of the development of resistance, the thickening of the epidermis, and the formation of immunity depending on age.

Despite the diversity of aetiological factors, parasitic dermatitis shares common pathogenetic features, namely the development of an inflammatory response, pruritus, a tendency towards chronicity, and frequent complications from secondary infection. At the same time, there are significant differences in the mechanisms underlying individual forms, which necessitate a differentiated approach to diagnosis and treatment. This indicates a lack of standardisation in contemporary understanding of the pathogenesis of parasitic dermatitis and highlights the need for further comprehensive research.

Clinical signs and diagnosis of parasitic dermatitis

Insects and mites parasitise on the skin and hair of dogs, causing skin and hair follicle lesions, inflammation, pruritus, alopecia, and the development of secondary infections. In their studies, M.A. Fouda *et al.* (2021) emphasised that the clinical picture is often non-specific, which is consistent with the findings of K. Mason & M. Ruutu (2023) regarding the difficulty of differentiating ectoparasitoses on the basis of clinical signs alone. Pruritus is the principal symptom of parasitic dermatitis. Some researchers associate these clinical signs with the effects of allergens produced by ectoparasites, whereas B.C.F. Nogueira *et al.* (2023) further clarified the role of immune hyperreactivity and mast cell degranulation. It is crucial to recognise that pruritus does not always accompany demodicosis, a fact that creates a diagnostic trap and points to a completely different pathogenic course for this disease. Erythema and inflammation represent a universal cutaneous response to infestation. A.K. Gupta *et al.* (2025) described these as a consequence of histamine release, whereas H.A. Zineldar *et al.* (2023) emphasised microvascular changes. When comparing these data, one can conclude that

clinical signs are the result of the combined effect of an immune and vascular response, and not of direct parasite exposure.

Alopecia (focal hair loss) is observed in most cases of parasitic dermatitis. According to A.D. Michalka *et al.* (2022), its pathogenesis is based on the destruction of hair follicles and chronic scratching. L.C. Panait *et al.* (2025) indicated that in trichodectosis, lesions are more spread, but in local infestations – within the reach of the animal's paws. This implies different severities of damage to the hair apparatus in various species of ectoparasites. With a chronic course of the disease, there is a development of hyperkeratosis, scales, and crusts. This is associated with the prolonged persistence of the parasites and constant stimulation of the inflammatory response. F. Moog *et al.* (2021) focused on the effect of long-term antigenic exposure, and V. Yevstafieva *et al.* (2024) noted the role of secondary bacterial infection as a cause of chronicity. Secondary infections are a common complication. Staphylococci, streptococci, and the fungus *Malassezia* are most frequently involved, leading to pyoderma, seborrhoeic dermatitis, unpleasant odour, and systemic intoxication (Hobi *et al.*, 2024). M. Kazemi (2025) pointed to the frequent involvement of staphylococci, while V. Brue *et al.* (2022) demonstrated that the microbiota determines the severity of the clinical course. This allows the conclusion that parasitic dermatitis should be regarded as a multifactorial pathology.

Clinical manifestations vary according to the type of parasite. M.A. Fouda *et al.* (2021) described flea allergy dermatitis as being characterised by papulo-crustous eruptions and intense pruritus in the region of the croup, tail, and hind limbs, whereas K. Mason & M. Ruutu (2023) emphasised behavioural changes in the animal as an early diagnostic marker. Louse infestation (trichodectosis) manifests as lesions of the skin of the neck, back, and flanks,

hair loss, and the presence of nits attached to hair shafts. A.D. Michalka *et al.* (2022) and L.C. Panait *et al.* (2025) pointed out the location of lesions on the neck and back, allowing for the detection of certain topographical specificity in parasitic dermatoses.

Sarcoptic mange is manifested by acute and persistent pruritus and lesions of the ears, elbows and belly. At the sites of parasite activity, papules with fluid content and thin, winding lines – the remnants of mite burrows – appear. F. Moog *et al.* (2021) described these “burrowing tunnels” as a pathognomonic sign, whereas V. Yevstafieva *et al.* (2024) emphasised the role of hypersensitivity, which explains the disparity between the low number of parasites and the high severity of clinical symptoms.

In otodectic mange, A. Melezhyk *et al.* (2024) pointed out more specific clinical signs: it scratches its ears, and from the auditory canal, there is an abundant, dark brown, tar-like secretion with an unpleasant smell. In demodicosis, the animal does not scratch as long as there is no secondary microbial infection. The main clinical signs are the appearance of areas of hair loss, peeling, inflammatory skin changes, and papules, which subsequently turn into pustules. In generalised forms, pustules merge into inflammatory infiltrates; the disease is accompanied by an unpleasant acid smell (“red mange”) (Kumar & Shekhar, 2020).

The final stage of the diagnosis of parasitic dermatitis is laboratory confirmation of the parasite. This includes the determination, identification and differentiation of parasites, as well as assessment of the severity of infestation. Diagnostic materials involve the collection of skin scrapings, exudate from the external auditory canal, contents of hair follicles, scales, crusts, hair, and earwax. For entomoses, parasites can be collected mechanically because of their usually visible size to the naked eye. Methods of diagnosis include microscopy

(light and electron) and sedimentation and flotation, culture methods, serological testing, and molecular genetic diagnostics (e.g. PCR for differentiation of the species belonging to *Demodex*). As emphasised by M. Ilie *et al.* (2021) and P. Thomson *et al.* (2023), these represent the transition to etiologically targeted diagnostics. The so-called “wet paper test” helps detect blood remains in flea faeces to diagnose flea allergy dermatitis. Nits attached to hair shafts or adults, as well as skin heating in some cases, aid in the diagnosis of pediculosis (Ali *et al.*, 2020). Other, more modern methods, such as serological assays and immunohistochemistry, are able to detect parasitic antigens and provide an accurate diagnosis. With the latter having special significance in differentiating parasitic conditions from allergic dermatoses, as emphasised by L. Chng *et al.* (2021).

Accordingly, the diagnosis of parasitic dermatitis is a complex process combining clinical assessment and laboratory investigation. It enables differentiation from other dermatological diseases, identification of the specific pathogenic role of the causative agent, and selection of an appropriate treatment regimen (Chng *et al.*, 2021). Therefore, the diagnosis of parasitic dermatitis is a complex process that combines clinical and laboratory methods and enables the differentiation of the disease from other types of dermatology, the identification of the pathological role of the aetiology and selection of the appropriate therapy.

Treatment and prevention of parasitic dermatitis

Therapy for parasitic dermatitis in dogs is a complex and multicomponent process that requires a combination of aetiotropic, pathogenetic and symptomatic methods. The purpose of therapy is not just the elimination of the parasite, but also the resolution of inflammation, restoration of the skin's protective barrier,

prevention of the development of secondary complications, and prevention of relapse. As indicated by V. Brue *et al.* (2022), modern treatment strategies are based on the principles of multimodality, adequate duration and monitoring of treatment effectiveness. Also, N. Amanzougaghene *et al.* (2020) emphasised that the high rate of mixed parasitic lesions and the development of resistance of some parasites to the usual drugs require constant improvement of the treatment strategy.

Modern forms of medication include systemic and topical treatments. As pointed out by V.E. Defalque (2022), combination therapy is the most effective, as it acts on various links of the life cycle of the parasite. The main groups of active substances include the following: isoxazolines (fluralaner, sarolaner, afoxolaner, and lotilaner) – modern systemic preparations that block the parasites' nerve channels, causing paralysis and death. According to I.L. Gonçalves *et al.* (2021), these pharmaceuticals act in a broad range, covering fleas, ticks, and some other ectoparasites, and provide an extended duration of protection ranging from 4 to 12 weeks (the specific term depends on the substance). Importantly, isoxazolines have advantages over older contact agents, namely the fact that a systemic effect is observed, regardless of the external integument's integrity. According to R. Chiummo *et al.* (2020), prolonged exposure to the acaricidal activity of fluralaner ensures therapeutic success in the treatment of sarcoptic mange. A similar view was expressed by M.O. Dumitrache & M. Cadiergues (2023), who, in a critical review of current studies, noted the high efficacy of fluralaner in canine sarcoptic mange and its advantage in terms of faster parasitological cure compared with certain macrocyclic lactones. At the same time, the authors also highlighted certain limitations associated with the use of isoxazolines. N. Bates *et al.* (2024) and D. Gaens *et al.* (2019)

reported the possibility of the emergence of adverse neurological reactions (tremors, ataxia, seizures). The authors emphasised the need for careful use of the described agents in dogs with a history of neurological disorders. Meanwhile, contemporary studies show the high safety level of isoxazolines in dogs and the superiority of these agents over older generations of insecto-acaricidal agents.

Macrocyclic lactones (ivermectin, moxidectin, selamectin) are widely used for treating ectoparasitic, parasitic, and helminth infections. According to C. Romero-Núñez *et al.* (2020), they exhibit high activity against mites and certain types of helminths but have some limitations in their use. In particular, in Collies, Shetland Sheepdogs, Australian Shepherds, and some related breeds, severe toxidermia is observed due to the presence of a mutation of the MDR1 gene. The authors emphasised that there is a trend in modern veterinary medicine towards the gradual replacement of macrocyclic lactones by isoxazolines because of the threat of neurotoxicity. Topical preparations remain an important place in the treatment, especially in the case of superficial forms of entomoses and mild forms of acariases. According to F. Martínez-Ibañez *et al.* (2026), amitraz is still used to treat generalised demodicosis due to its pronounced acaricidal activity. However, the use of the latter is restricted due to the high toxicity and risk of side effects (sedation, hypothermia, bradycardia, local reactions in the form of irritation). Fipronil exhibits a better safety profile than amitraz. Fipronil-based preparations have been shown by I. Yuskiv *et al.* (2024; 2025) to be especially active against fleas and lice, while being significantly inferior to systemic agents in the treatment of sarcoptic mange and demodicosis. It can be concluded that when selecting the most suitable treatment strategy, it is necessary to take into account the type of parasite involved, the severity

of the condition, and the general condition of the animal. In the research of O.V. Kruchynenko (2020), it is shown that in the set of agents used to treat and prevent ectoparasitoses in dogs, preparations based on fipronil, permethrin, or selamectin prevail.

There is a current trend in veterinary dermatology towards comprehensive and combined approaches to the treatment of parasitic dermatitis, involving the use of both systemic and topical insectoacaricidal agents. R.S. Mueller *et al.* (2012) noted in their clinical guidelines for the treatment of canine demodicosis that successful treatment should not only be aimed at eradicating parasites but also at eliminating predisposing factors such as immunodeficiency, endoparasitism, endocrinopathy, and secondary bacterial infections. It is also noted that generalised demodicosis is often accompanied by pyoderma, in which case it is recommended to conduct additional treatment with topical or systemic antimicrobials. The authors found that amitraz given once a week was effective, as well as the use of macrocyclic lactones: ivermectin, milbemycin oxime, and moxidectin. On the other hand, the authors noted that in sensitive animals, especially herding breeds, there may be a risk of side effects in the form of neurotoxicity; therefore, these drugs should be used slowly in a dose-escalating fashion and be closely monitored. Furthermore, V. Brue *et al.* (2022) state that depending on the form and severity of parasitic skin diseases, the speed of response to treatment and the effectiveness of specific aetiotropic treatment can differ. On these grounds, after establishing the correct diagnosis, they suggest adding symptomatically applied antipruritic drugs, which improve the quality of life for both the pet and the owner.

A separate place in the scheme of current prevention and treatment of ectoparasitoses is taken by combined topical formulations. In this respect, the study by M. Varloud &

J.J. Fourie (2015), in which the efficacy of three topical ectoparasiticides was compared against ticks of *Rhipicephalus sanguineus* in dogs, is worth noting. According to these authors, the products containing permethrin had a better and longer-lasting residual acaricidal action than those containing fipronil. Thus, using the product Vectra 3D (dinotefuran, permethrin and pyriproxyfen) ensured more than 90% protection for one month after the first application, while products based on fipronil showed much lower efficacy. They also emphasised that formulations containing permethrin act faster and have an excellent repellent effect on ticks and fleas, which is important to prevent reinfection. Therefore, based on the analysis of this information, it is clear that combined formulations are more effective for treating ectoparasitoses, since their use includes both acaricidal and repellent activity and also acts against different stages of the life cycle.

In addition, great importance in this field is given to the treatment of secondary infection caused by parasitic dermatitis. It is known that to combat secondary infections in the skin of animals, various antibiotics and antifungals are used, depending on the susceptibility of the microflora. A. Loeffler *et al.* (2025) note that chronic skin damage and persistent self-trauma create favourable conditions for the development of bacterial pyoderma and *Malassezia* dermatitis. According to J. Miller *et al.* (2023), effective insectoacaricidal therapy cannot bring about full recovery in dogs with secondary microflora; therefore, in cases of chronic dermatitis, it is recommended to carry out a bacteriological examination and determine the microflora's sensitivity to antibiotics. In addition to etiotropic therapy, pathogenic and symptomatic treatment is also important. According to M. Kazemi (2025), the use of omega-3 fatty acids, zinc, B-group vitamins, and antioxidants improves the restoration of the

epidermal barrier and reduces the intensity of inflammation. In addition, R.S. Mueller *et al.* (2012) reported a beneficial effect of immunotherapy in dogs with generalised demodicosis, especially those with relapses. This analysis of the described treatment methods shows that modern therapy for parasitic dermatitis is primarily directed at restoring the functional state of the skin and the immune reactivity of the host animal.

Prophylactic management of parasitic dermatitis is one of the main measures to reduce the incidence of ectoparasitosis. According to J. Miller *et al.* (2023), controlling parasitic factors is a key element in the prevention of secondary dermatological conditions. Preventive measures are primarily based on regular application of insectoacaricidal agents, sanitary treatment of premises, and control of contact between animals. V. Colella *et al.* (2020) emphasise that inadequate preventive treatment compliance is one of the most important risk factors for relapses of flea allergy dermatitis in urban dogs. The results of any preventive measures are greatly influenced by the quality of the comprehensive approach applied. In a comparative study of ectoparasiticides, M. Varloud & J.J. Fourie (2015) emphasised that control of tick and flea infestations should involve regular animal treatment along with environmental and in-contact animal management to reduce the risk of reinfestation. Moreover, the seasonal increase in tick activity in summer should be mentioned as a risk factor necessitating more careful preventive measures. At the same time, C. Becskei *et al.* (2016) in a multilevel study on sarolaner efficacy, the authors reported that the long-term use of modern systemic isoxazolines ensures a high level of anti-flea/anti-tick protection. Rapid elimination of parasites by using these treatments may be considered a significant component contributing to the reduction of clinical manifestations of flea allergy derma-

titis. Another very important part of prevention is to conduct educational work with the owners of animals. According to V. Brue *et al.* (2022), many recurrent cases are due to delayed or poorly performed antiparasitic treatment. The authors suggest that educating the owners about the biology and epidemiology of the parasite (its cycle of development, ways of transmission, and the need for preventive treatment) may significantly improve the results.

In conclusion, modern treatment approaches to parasitic dermatitis should involve a combined strategy of treatment with systemic and topical insectoacaricidal agents, secondary infection control and restoration of normal skin physiology. Based on an analysis of recent research, the most promising strategy appears to be the combined use of therapeutic protocols based on a broadspectrum agent, primarily isoxazolines. At the same time, treatment outcomes depend largely on timely prevention, sanitary control, and adherence to regular treatment schedules for animals.

Conclusions

The study involved a systematic review of the current scientific literature on the causes and mechanisms of the disease, the clinical course, diagnosis and treatment of parasitic skin diseases in dogs. This study analyses modern approaches to the formation of the aetiology of parasitic diseases, mechanisms of their occurrence, methods of clinical diagnosis and treatment of the disease. It is established that parasitic dermatitis is a polyetiological disease that develops due to the effect of various types of ectoparasites and abiotic factors. The analysis shows that the pathogenesis of these diseases is multifactorial and includes damage to the skin with mechanical factors, the manifestation of an immune response, and the development of secondary infectious processes. The clinical course of parasitic skin lesions is often

similar in terms of the signs of manifestation, which makes it difficult to accurately diagnose parasitic dermatitis without laboratory testing. It has been established that modern diagnostic approaches are based on a combination of traditional and molecular methods, each of which has its own advantages and limitations. Modern methods of treating parasitic dermatitis are considered to be the most effective, which include the combined use of modern insectoacaricidal drugs, symptomatic and pathogenetic therapy, as well as the prevention of the disease. The findings obtained synthesise current understanding of parasitic dermatitis in dogs and confirm its multifactorial nature, which underlines the need for a systematic approach to both study and control. This is of considerable importance for the development of veterinary dermatology and for improving the effectiveness of clinical veterinary practice.

Future studies should include a more thorough study of the morphological changes in the skin during different forms of parasitic damage, immunological reasons for the development of these pathologies, and ways of their differential diagnosis and treatment. It is expected that the results of an in-depth morphological

and immunological analysis will help to clarify the mechanisms of skin damage, as well as the role of immune sensitisation and secondary microflora in the development of the pathological process. They will also contribute to the development of criteria for the early diagnosis of these diseases, improve their differentiation and substantiate personalised treatments depending on the species of the parasite and individual immune reactivity of the patient. Furthermore, the anticipated results will serve as the basis for the formation of effective methods of prevention and treatment, contributing to the reduction of the number of recurrent skin diseases and the prevention of the appearance of complications, and increasing the overall quality of veterinary treatment of dogs suffering from parasitic dermatitis.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Дерматит паразитарної етіології в собак: огляд літератури щодо клініко-діагностичних аспектів та підходів до лікування

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Анотація. Дерматит паразитарної етіології в собак є однією з найбільш поширених і актуальних проблем сучасної ветеринарної медицини через високу частоту реєстрації та значний вплив на здоров'я тварин. Метою роботи було узагальнення сучасних даних щодо поширення, етіології, патогенезу, клінічних симптомів, діагностики та лікування собак за дерматиту паразитарної етіології. У роботі використано методи аналізу та узагальнення наукових літературних джерел. Встановлено, що дерматит паразитарної етіології має поліетіологічну та багатофакторну природу і найчастіше спричиняється ектопаразитами, зокрема блохами, вошами, волосоїдами та кліщами. Доведено, що провідне місце у структурі захворюваності займає алергічний блошиний дерматит, тоді як значну роль відіграють акарози, які характеризуються високою контагіозністю та схильністю до хронічного перебігу. Визначено, що клінічні прояви є переважно неспецифічними та включають свербіж, еритему, алопеції, утворення кірок і лусочок, а також ускладнюються вторинними бактеріальними і грибковими інфекціями, що ускладнює диференційну діагностику. Обґрунтовано, що ключовим етапом встановлення діагнозу є лабораторна індикація та ідентифікація збудників із застосуванням мікроскопічних, серологічних і молекулярно-генетичних методів. Показано, що сучасні підходи до лікування базуються на застосуванні інсектоакарицидних препаратів, зокрема ізоксазолінів і макроциклічних лактонів, у поєднанні з комплексною терапією вторинних ускладнень та профілактичними заходами. Практична цінність роботи полягає в узагальненні сучасних наукових підходів до діагностики, лікування та профілактики в собак дерматиту паразитарної етіології для підвищення ефективності ветеринарної практики

Ключові слова: ектопаразити; алергічні реакції шкіри; патогенез; діагностика; інсектоакарицидна терапія; вторинні інфекції



Effects of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) supplementation on reproductive performance, embryogenesis, physiological parameters and oxidative stress in Japanese quails

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Abstract. The aim of this research was to scrutinise the influence of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) supplementation on embryogenesis, physiological parameters and oxidative stress of Japanese quails. Four dietary treatments were used consisting of a control diet and diets enriched with garlic, ginger, and their combination. A total number of 180 laying birds were randomly allocated to the four treatments consisting of 3 replicates with 15 birds per replicate. Four hundred and eighty eggs were collected for embryogenesis study after the birds had been on the experimental diets for four weeks. Data were analysed using one-way analysis of variance (ANOVA) in SPSS. Fertility percentage and reproductive capacity significantly increased in the treated groups

Suggested Citation:

Nkankeya, G., Musa-Azara, I., & Idahor, K.O. (2026). Effects of garlic (*Allium sativum*) and ginger (*Zingiber officinale*) supplementation on reproductive performance, embryogenesis, physiological parameters and oxidative stress in Japanese quails. *Ukrainian Journal of Veterinary Sciences*, 17(2), 43-56. doi: 10.31548/veterinary2.2026.43.

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while a combination of ginger and garlic resulted in higher percentage of hatchability of fertile eggs. All treatments culminated in a significant increase in crown-rump length ($P < 0.05$) while embryonic weights were similar for all treatments. Significant improvement was recorded in total antioxidant capacity of birds administered ginger, garlic, and a concomitant use of ginger and garlic although oxidative stress index values were statistically indistinguishable across all treatments ($P > 0.05$). Serum level of IgG was improved following treatment with garlic ($P < 0.05$). Whereas the serum level of IgE was significantly elevated as a result of ginger administration while a combination of ginger and garlic resulted in elevated levels of IgM ($P < 0.05$). Total cholesterol decreased significantly due to the combination of ginger and garlic. Combination of ginger and garlic also resulted in improved haematological parameters. Garlic administration elicited a significant increase ($P < 0.05$) in total protein while other parameters were similar. So, ginger and garlic positively influenced fertility, embryonic growth-related traits, immunity and antioxidant defence in Japanese quails, supporting their use as safe natural feed additives

Keywords: phytogetic additive; hatchability; humoral immunity; antioxidant capacity; lipid metabolism; haematology; serum biochemistry

Introduction

Sustainable production of healthy poultry birds that is not detrimental to consumers' health have been of great concern in recent years. Various studies have increasingly focused on natural feed additives, such as phytochemicals, to enhance bird performance, immunity, and overall physiological well-being. N. Aminullah *et al.* (2025) reported that because of concerns about antimicrobial resistance and food safety, phytochemical feed additives (PFAs) have become increasingly considered sustainable alternatives to antibiotic feed additives in poultry production. This could have resulted as a response to human requests for more natural food and the cost implications of these antibiotics. According to N. Abdelli *et al.* (2021), PFAs, also called phytochemicals, are natural plant-based substances added to animal feed without harming the animals. They improve gastrointestinal health, systemic function, productivity, and welfare, while reducing morbidity and mortality. PFAs also provide antioxidant and immune support, and combining them can lower inclusion

levels, reduce feeding costs, and enhance overall results compared with single additives.

G. Dosu *et al.* (2023) reported that ginger (*Zingiber officinale* Roscoe) is widely used as a natural feed additive due to its rich bioactive compounds, including gingerols, shogaols, gingerdione, and phenolic ketones. It has antioxidant, anti-inflammatory, and immunomodulatory properties, supporting animal health and disease resistance. Additionally, ginger improves cellular function, lipid metabolism, and digestion, enhancing nutrient absorption, growth performance, and feed efficiency. As a phytochemical additive, it offers a sustainable alternative to synthetic growth promoters and antibiotics. W.A. Abd El-Ghany (2024) noted that garlic, as a natural feed additive, contains bioactive compounds such as allicin, diallyl sulphides, alliin, saponins, phenols, amino acids, vitamins, minerals, and essential oils, providing antioxidant, antimicrobial, anti-inflammatory, and immune-modulating effects. In poultry, garlic is used in powder, extract, oil, or commercial supplement forms to improve blood

parameters, enhance immunity, reduce infections, and alleviate heat stress.

Scientists O.E. Oke *et al.* (2025) described Japanese quails (*Coturnix japonica*) as small poultry birds majorly reared for both meat and egg production and currently gaining increasing attention in the poultry industry due to their rapid growth, early maturity, and high egg-laying ability, with the ability to begin egg production at about 40-42 days of age and annual production of over 200 eggs per bird under proper management. Distinguished by their small body size, efficient feed conversion, low maintenance requirement and relatively hardy and resistant to many common poultry diseases, makes them easy to manage and suitable for small-scale and backyard farming systems. As reported by A.F. Abdul-Majeed & S.Y. Abdul-Rahman (2022) ginger prevented the effects of oxidative stress and most of the biochemical values were the same as in the control group in H₂O₂-induced oxidative stress research, significantly increasing glutathione 2.92 µmol/l while the value of the stress index (malondialdehyde 0.41 nmol/ml) were reduced signifying a deduction in harmful free radical that can cause cell damage when elevated thus concluded that ginger have the ability to improve blood parameters and serum antioxidants status. Research by Z. Nemati *et al.* (2021) using 240 laying quails reported that Ginger root Powder administered at different doses reduced blood triglyceride levels though was not effective on blood total antioxidant capacity and malondialdehyde.

Researchers M.I Abo-Samaha & H.A. Basha (2021) evaluated the effect of garlic oil spray before the inception of incubation and continuing its application for the first 10 days in incubator showed that at 2% of the garlic solution spray and reported remarkable hatchability increases of the fertile Japanese quail. A study by W.M. Dosoky *et al.* (2024) on 300 quails fed a cadmium-contaminated diet showed a

significant reduction in immunoglobulin, especially IgM. Supplementation with vitamin C (200 mg/kg), dried garlic powder (500 mg/kg), or their combination improved IgM and IgG levels, mitigating cadmium's harmful effects. This demonstrates the detoxifying and immune-boosting properties of garlic and vitamin C. Nevertheless, there is still limited research on inclusion level, embryogenesis, antioxidant status, serum immunoglobulins, and blood parameters in Japanese quail under local production conditions. Thus, this research is aimed to help bridge this knowledge gap, ensuring data-driven recommendations that could enhance both the productivity and the product quality using natural feed additives, and ensuring safe consumption.

The aim of this study was to evaluate the effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on embryogenesis, physiological parameters and oxidative stress of Japanese quail. Specifically, the objectives were to:

- ♦ evaluate the effects of dietary ginger, garlic, and their combination on fertility, hatchability, reproductive capacity, and embryonic development of Japanese quails;
- ♦ assess the effects of dietary ginger, garlic, and their combination on antioxidant status and serum immunoglobulin responses;
- ♦ examine the effects of dietary ginger, garlic, and their combination on lipid profile, haematological indices, and serum biochemical parameters.

Materials and Methods

The experiment was conducted at the Teaching and Research Farm of the Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus. The study area lies within the Guinea Savanna zone of North Central Nigeria and is located at latitude 08°35'N and longitude 08°33'E. The study was conducted using a Completely Randomised Design. A total of 180

laying Japanese quails were used for this research. The birds were randomly assigned to 4 dietary treatments, each replicated 3 times, giving 45 birds per treatment and 15 birds per replicate. Treatment 1, which is the control, contained neither ginger nor garlic. Treatment 2 was fed 20 g of ginger per kg of feed. Treatment 3 was fed 20 g of garlic per kg of feed, whereas Treatment 4 was fed 20 g each of ginger and garlic per kg of feed. The feeding trial lasted for 8 weeks.

The experimental birds were sourced from the National Veterinary Research Institute, Vom, Plateau State. Upon arrival, the birds were kept for 4 weeks before the inception of the feeding trial to allow for adequate acclimatisation and rest. All procedures were conducted in accordance with the ARRIVE guidelines (n.d.) and approved ethical standards for the care and use of animals in research. The birds were housed in battery cages inside the teaching and research farm facility. Before stocking, the cages and pens were washed, disinfected, and allowed to dry for a week. Adequate ventilation, lighting, and strict biosecurity were maintained throughout the experiment. Birds had ad libitum access to clean water and experimental diets. Fresh garlic bulbs and ginger rhizomes were purchased from a local market, cleaned, sliced, air-dried, and ground into powder before incorporation into the experimental diets.

A total of 480 eggs were collected after four weeks of dietary treatment and incubated under standard incubation conditions. Fertility, hatchability, reproductive capacity, embryonic weight, and crown-rump length were evaluated during the incubation period. Embryogenesis was evaluated during the incubation period using measurements of embryonic weight and crown-rump length. On days 5, 10, and 15 of incubation, selected eggs were carefully opened and embryos were removed for embryonic measurements. Embryonic weight was measured

using a digital weighing balance, while crown-rump length was measured in millimetres using a digital Vernier calliper. Morphological observations, including feather development and visible abnormalities, were also recorded.

Fertility percentage was calculated using the formula:

$$\text{Fertility (\%)} = \left(\frac{\text{Number of fertile eggs}}{\text{Total eggs set}} \right) \times 100, \quad (1)$$

where *Number of fertile eggs* = eggs that showed evidence of embryonic development after candling or egg break-out examination; *Total number of eggs set* = total number of eggs placed in the incubator for hatching. Hatchability percentage was calculated using the formula:

$$\text{Hatchability (\%)} = \left(\frac{\text{Number of hatched chicks}}{\text{Total fertile eggs}} \right) \times 100, \quad (2)$$

where *Number of hatched chicks* = total number of chicks successfully hatched from fertile eggs; *Total number of fertile eggs* = eggs confirmed fertile during incubation assessment.

Reproductive capacity percentage was calculated using the formula:

$$\text{Reproductive capacity (\%)} = \left(\frac{\text{Number of hatched chicks}}{\text{Total eggs set}} \right) \times 100, \quad (3)$$

where: *Number of hatched chicks* = total number of chicks successfully produced from the eggs set; *Total number of eggs set* = total number of eggs incubated during the experiment. Fertility percentage was used to evaluate the proportion of eggs that were fertile after incubation. Hatchability percentage was used to determine the proportion of fertile eggs that successfully hatched, while reproductive capacity percentage was used to assess the overall efficiency of chick production from the total eggs incubated.

Total oxidative stress was determined using the automated colorimetric method described by O. Erel (2005). In this assay, oxidant molecules in the serum oxidise the ferrous

ion-o-dianisidine complex to ferric ions, which then react with xylenol orange in an acidic medium to produce a coloured complex. The intensity of the colour formed was measured spectrophotometrically and was proportional to the total oxidant concentration of the sample. Total antioxidant capacity was determined using an ABTS-based spectrophotometric assay according to O. Erel (2004). Antioxidants present in the sample reduce the pre-formed ABTS radical cation, causing decolourisation of the blue-green chromophore. The decrease in absorbance was measured spectrophotometrically and was proportional to the antioxidant capacity of the sample. Results were expressed as Trolox equivalent antioxidant capacity.

Serum immunoglobulins IgG, IgM, and IgE were determined using the sandwich enzyme-linked immunosorbent assay technique. Blood samples were allowed to clot and were centrifuged at 3,000 rpm for 15 min to obtain serum. Serum samples were added into microplate wells pre-coated with antibodies specific to the immunoglobulin of interest. Enzyme-linked secondary antibodies were then added, followed by a chromogenic substrate after incubation. The reaction was stopped and absorbance was measured at 450 nm using a microplate reader. Immunoglobulin concentrations were obtained from a standard calibration curve based on the ELISA principle of E. Engvall & P. Perlmann (1971). Total cholesterol, triglycerides, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol were determined using Randox® kits following standard enzymatic colorimetric procedures and the manufacturer's instructions. Low-density lipoprotein cholesterol was calculated using the Friedewald formula (4) (Friedewald et al., 1972):

$$LDL-C = TC - HDL-C - (TG/2.2), \quad (4)$$

where *LDL-C* = low-density lipoprotein cholesterol, *TC* = total cholesterol, *HDL-C* = high-

density lipoprotein cholesterol, *TG* = triglycerides, the factor 2.2 was used because lipid concentrations were expressed in mmol/L.

Blood (2 mL) was collected into K₃-EDTA anticoagulant tubes for haematological analysis. Packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count were determined. Packed cell volume was measured by the microhematocrit method, haemoglobin concentration by the cyanmethemoglobin method, while red and white blood cell counts were estimated using a hemocytometer as described by S.M. Lewis et al. (2011).

Serum samples were analysed for total protein, albumin, urea, and creatinine using a Vita lab Selectra E clinical chemistry analyser according to the manufacturer's standard analytical procedures. Total protein was determined by the biuret method, albumin by the bromocresol green method, urea by the urease – Berthelot reaction, and creatinine by the Jaffe reaction. The analyser measured absorbance and automatically converted the readings to concentrations based on the instrument calibration settings.

Data on hatchability, embryogenesis, oxidative stress markers, serum immunoglobulins, lipid profile, serum biochemical parameters, and haematological parameters were subjected to one-way analysis of variance (ANOVA) in SPSS version 25. Treatment means were separated using Duncan's multiple range test, and significance was declared at $P < 0.05$ (Duncan, 1955):

$$Y_{ij} = \mu + T_i + e_{ij}, \quad (5)$$

where Y_{ij} = individual observation, μ = overall mean, T_i = effect of the i th dietary treatment, and e_{ij} = random experimental error.

Results and Discussion

The effects of dietary garlic, ginger, and their combination on reproductive performance, embryogenesis, oxidative stress, serum

immunoglobulins, lipid profile, and haematological and biochemical parameters of Japanese quails were evaluated. Values are presented as mean $\pm$ standard deviation, with significant differences indicated at $P < 0.05$. Table 1 presents the effects of dietary garlic, ginger, and their combination on fertility, hatchability, and reproductive capacity of Japanese quails. Fertility percentage differed significantly among

treatments ($P < 0.05$), with the garlic-supplemented and combined ginger-garlic groups showing higher fertility values than the control group. Hatchability of fertile eggs was not significantly affected by dietary treatments ($P > 0.05$). Reproductive capacity significantly increased in the supplemented groups, particularly in birds administered the combined ginger-garlic diet.

Table 1. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on fertility and hatchability of Japanese quail

Parameter	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	P-value
Fertility (%)	88.00 $\pm$ 4.00 ^b	90.67 $\pm$ 10.07 ^b	94.67 $\pm$ 2.31 ^a	93.33 $\pm$ 6.11 ^a	0.041*
Hatchability (FE, %)	91.11 $\pm$ 7.36 ^a	90.09 $\pm$ 11.02 ^a	88.77 $\pm$ 4.79 ^a	92.85 $\pm$ 2.43 ^a	0.612 ^{ns}
Reproductive Capacity (%)	80.00 $\pm$ 4.00 ^b	81.33 $\pm$ 10.07 ^b	84.00 $\pm$ 4.00 ^{ab}	86.67 $\pm$ 6.11 ^a	0.048*

Note: means with different superscripts (a, b) differ significantly at $P < 0.05$; mm = millimetres; g = grams; NS = not significant; * – significant

Source: authors' experimental data

Table 2 shows the effects of dietary garlic, ginger, and their combination on embryonic development of Japanese quails. Crown-rump length significantly increased in all supplemented groups compared with the control group ($P < 0.05$),

indicating enhanced embryonic growth. However, embryonic weight did not differ significantly among treatments ($P > 0.05$), suggesting that dietary supplementation mainly influenced embryonic linear growth rather than embryo mass.

Table 2. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on embryogenesis of Japanese quail

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
Crown-Rump Length (mm)	24.09 $\pm$ 0.99 ^b	28.19 $\pm$ 1.01 ^a	28.18 $\pm$ 0.98 ^a	28.22 $\pm$ 1.11 ^a	0.0002*
Embryonic Weight (g)	1.01 $\pm$ 0.02	1.32 $\pm$ 0.14	1.27 $\pm$ 0.12	1.25 $\pm$ 0.11	0.8533 ^{ns}

Note: means with different superscripts (a, b) differ significantly at $P < 0.05$; mm = millimetres; g = grams; NS = not significant; * – significant

Source: authors' experimental data

Table 3 presents the effects of dietary garlic and ginger supplementation on oxidative stress markers of Japanese quails. Total antioxidant capacity significantly increased in the supplemented groups, especially in birds fed ginger and the ginger-garlic combination diets ($P < 0.05$).

Total oxidant status also varied significantly among treatments, while oxidative stress index values were not significantly different ($P > 0.05$). These findings suggest that dietary supplementation improved antioxidant responses without causing marked oxidative imbalance.

Table 3. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on antioxidant capacity and total oxidative stress of Japanese quails

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
TAC (mmol/L)	244.94 ± 12.45 ^c	308.47 ± 4.32 ^a	287.83 ± 10.31 ^b	311.57 ± 2.41 ^a	0.0001*
TOS (μmol/mL)	2.73 ± 0.19 ^c	3.19 ± 0.14 ^b	4.07 ± 0.05 ^a	3.35 ± 0.84 ^b	0.0044*
OSI	0.01 ± 0.00	0.00 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.0594 ^{ns}

Note: means with different superscripts (a, b, c) differ significantly at $P < 0.05$; TAC = total antioxidant capacity, TOS = total oxidant status, OSI = oxidative stress index, mmol/L = millimoles per litre, μmol/mL = micromoles per millilitre, NS = not significant; * – significant

Source: authors' experimental data

Table 4 shows the effects of dietary supplementation on serum immunoglobulin concentrations of Japanese quails. Significant differences were observed among treatments for IgG, IgM, and IgE levels ($P < 0.05$). Garlic

supplementation improved IgG concentration, while the combined ginger-garlic treatment produced the highest IgM values. Ginger supplementation resulted in elevated IgE concentration compared with other treatments.

Table 4. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on the serum level of immunoglobulin of Japanese quails

Parameter (g/L)	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
IgG	6.00 ± 0.40 ^a	5.13 ± 0.15 ^b	7.77 ± 0.38 ^a	5.97 ± 0.04 ^b	0.0023*
IgM	1.04 ± 0.08 ^c	0.87 ± 0.09 ^c	1.20 ± 0.06 ^b	2.23 ± 0.012 ^a	0.0000*
IgE	2.00 ± 0.06 ^b	3.33 ± 0.18 ^a	2.17 ± 0.09 ^b	1.47 ± 0.07 ^c	0.0000*

Note: means with different superscripts (a, b, c) differ significantly at $P < 0.05$; IgG = immunoglobulin G; IgM = immunoglobulin M; IgE = immunoglobulin E; * – significant

Source: authors' experimental data

Table 5 presents the effects of dietary supplementation on lipid profile of Japanese quails. Total cholesterol significantly decreased in birds administered the combined ginger-garlic diet compared with the control group ($P < 0.05$). High-density lipoprotein cholesterol

improved in supplemented groups, while low-density lipoprotein cholesterol and triglyceride concentrations were reduced, especially in garlic-treated birds. These findings indicate improved lipid metabolism following dietary supplementation.

Table 5. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on Lipid profile of Japanese Quail

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	p-value
TC (mmol/L)	3.73 ± 0.12 ^{ab}	3.30 ± 0.15 ^b	3.57 ± 0.09 ^c	2.97 ± 0.03 ^a	0.0139*
HDL (mmol/L)	1.06 ± 0.03 ^b	1.27 ± 0.03 ^a	1.07 ± 0.09 ^b	1.30 ± 0.06 ^a	0.0328*
LDL (mmol/L)	1.47 ± 0.09 ^a	1.60 ± 0.06 ^a	0.99 ± 0.07 ^b	1.40 ± 0.06 ^a	0.0321*
TG (mmol/L)	1.40 ± 0.06 ^a	1.60 ± 0.06 ^a	0.99 ± 0.09 ^b	1.40 ± 0.06 ^a	0.0019*

Note: means with different superscripts (a, b, c) differ significantly at $P < 0.05$; TC = total cholesterol; HDL = high-density lipoprotein; LDL = low-density lipoprotein; TG = triglycerides; * – significant

Source: authors' experimental data

Table 6 shows the effects of dietary garlic and ginger supplementation on haematological parameters of Japanese quails. Packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count differed significantly among treatments

($P < 0.05$). The combined ginger-garlic treatment produced the highest values for packed cell volume, haemoglobin concentration, and red blood cell count, suggesting improved oxygen-carrying capacity and physiological status of the birds.

Table 6. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on haematological parameters of Japanese quails

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	P-value
PCV (%)	34.66 ± 0.88 ^b	31.00 ± 0.58 ^c	34.00 ± 0.57 ^b	39.67 ± 0.88 ^a	0.0003*
Hb (g/dL)	10.87 ± 0.72 ^b	9.73 ± 0.21 ^c	11.03 ± 0.37 ^b	12.26 ± 0.12 ^a	0.0024*
RBC (×10 ¹² /L)	3.31 ± 0.07 ^b	3.08 ± 0.02 ^c	3.43 ± 0.07 ^b	3.92 ± 0.08 ^a	0.000*
WBC (×10 ⁹ /L)	10.37 ± 1.94 ^b	9.33 ± 5.04 ^b	13.30 ± 1.73 ^a	14.00 ± 0.58 ^a	0.003*

Note: means with different superscripts (a, b, c) differ significantly at $P < 0.05$; PCV – packed cell volume; Hb – haemoglobin; RBC – red blood cells; WBC – white blood cells; * – significant

Source: authors' experimental data

Table 7 shows the serum biochemical parameters of Japanese quails across the different treatments. There are significant differences at $P < 0.05$ among treatments for total protein, globulin, urea, creatinine, sodium (Na⁺), and potassium (K⁺), while albumin did not differ significantly among treatments ($P > 0.05$). Total protein values were highest in Treatments 1 and 3, while Treatment 2 recorded the lowest value. Globulin concentration was highest in

Treatment 1 and lowest in Treatment 3. Urea levels were highest in Treatment 2 and lowest in Treatment 3, whereas creatinine concentration was highest in Treatment 3 and lowest in Treatment 1. Sodium (Na⁺) concentration was highest in Treatment 3, with Treatments 1, 2, and 4 showing similar values and no significant differences among them. Potassium (K⁺) concentration was highest in Treatment 4 and lowest in Treatment 2.

Table 7. Effect of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) on serum biochemical parameters of Japanese quails

Parameters	Control	Ginger (20 g/kg)	Garlic (20 g/kg)	Ginger/Garlic (20 g/kg each)	P-value
Total protein (g/L)	53.00 ± 1.53 ^a	41.33 ± 1.45 ^c	59.00 ± 0.58 ^a	45.33 ± 0.88 ^b	0.0004*
Albumin (g/L)	20.67 ± 0.88	19.00 ± 0.58	22.67 ± 1.45	21.67 ± 0.88	0.1388 (NS)
Globulin (g/L)	31.33 ± 0.09 ^a	22.67 ± 0.09 ^b	15.75 ± 0.12 ^c	22.87 ± 0.09 ^b	0.0001*
Urea (mmol/L)	2.13 ± 0.08 ^b	3.17 ± 0.09 ^a	1.75 ± 0.12 ^c	2.28 ± 0.09 ^b	0.0001*
Creatinine (μmol/L)	38.67 ± 0.88 ^c	55.33 ± 2.73 ^b	63.00 ± 1.53 ^a	53.00 ± 0.58 ^b	0.0000*
Na ⁺ (mmol/L)	152.00 ± 1.50 ^b	148.00 ± 1.53 ^b	158.33 ± 1.20 ^a	152.00 ± 0.58 ^b	0.0047*
K ⁺ (mmol/L)	5.87 ± 0.08 ^{ab}	5.70 ± 0.06 ^b	5.90 ± 0.06 ^{ab}	6.13 ± 0.12 ^a	0.0414*

Note: means with different superscripts (a, b, c) within the same row differ significantly at $P < 0.05$; NS = not significant; * – significant

Source: authors' experimental data

The significant improvement in fertility percentage observed in garlic- and ginger-supplemented groups suggests that these phyto-genic additives may support reproductive efficiency and embryo viability in Japanese quails. The higher fertility values recorded in the garlic and combined ginger-garlic groups may be associated with the antioxidant and antimicrobial properties of the bioactive compounds present in these additives, particularly allicin in garlic and gingerols in ginger, which may improve physiological stability and reproductive function. However, hatchability of fertile eggs was not significantly affected among treatments, although numerically higher values were observed in the combined supplementation group. This indicates that while supplementation may improve fertilisation and embryo survival, it may not necessarily influence the final hatching process under the present experimental conditions. The improved reproductive capacity recorded in the supplemented groups further supports the beneficial role of garlic and ginger in enhancing overall reproductive output. Similar findings were reported by M.M.A. El-Kashef & M.I. El Sabry (2025), who observed that the use of ginger and garlic solutions affected embryonic development, hatchability, blood parameters and post-hatch performance in Japanese quails. The significant increase in crown-rump length observed in all supplemented groups indicates that dietary garlic and ginger supported embryonic growth and development during incubation. This effect may be attributed to the antioxidant properties of the phyto-genic compounds, which could help reduce oxidative damage during embryogenesis and support proper tissue development. Although embryonic weight numerically increased in supplemented groups, the differences were not statistically significant, suggesting that supplementation mainly influenced embryonic linear growth rather than embryo

mass accumulation. Enhanced nutrient utilisation and improved physiological conditions during incubation may also have contributed to the observed increase in crown-rump length. The improvement in crown-rump length recorded in the present study is supported by M.M.A. El-Kashef & M.I. El Sabry, who reported that ginger and garlic solutions influenced embryonic development and hatchability traits in Japanese quail. The significant increase in total antioxidant capacity recorded in birds fed ginger, garlic, and their combination indicates enhanced antioxidant defence following dietary supplementation. Ginger contains bio-active compounds such as gingerols, shogaols, and phenolic derivatives, while garlic contains sulphur-containing compounds including allicin and diallyl sulphides, all of which possess antioxidant properties capable of scavenging free radicals and reducing oxidative damage. The higher total antioxidant capacity observed particularly in the ginger and combined supplementation groups suggests improved ability of the birds to neutralise reactive oxygen species. Although total oxidant status varied significantly among treatments, oxidative stress index values did not differ significantly, indicating that oxidant and antioxidant activities remained relatively balanced.

These findings agree with those of B. Sevim (2026) reported that fermented black garlic powder supplementation improved antioxidant status, immune response, serum parameters, and performance-related traits in Japanese male quails. The significant differences observed in serum immunoglobulin concentrations indicate that dietary garlic and ginger supplementation influenced immune responsiveness in Japanese quails. Garlic supplementation resulted in higher IgG concentration, while the combined ginger-garlic treatment produced the highest IgM values, suggesting enhanced humoral immune activity. The

elevated IgE concentration observed in the ginger group may reflect stimulation of immune responsiveness by the phytochemical compounds present in ginger. The immunomodulatory effects observed in this study may be linked to the antioxidant and antimicrobial activities of garlic and ginger bioactive compounds, which could enhance antibody production and improve immune function. The improvement in serum immunoglobulin concentrations observed in the present study agrees with B. Sevim, who reported that fermented black garlic powder supplementation improved immune response and serum parameters in Japanese male quails. M. Fathi *et al.* (2025) also found that black garlic powder influenced immunoglobulin protein levels, haematological indicators and antioxidant capacity in broiler chickens.

The reduction in total cholesterol and triglyceride concentrations observed in supplemented birds suggests improved lipid metabolism following garlic and ginger administration. The combined ginger-garlic treatment produced the lowest total cholesterol values, while garlic supplementation significantly reduced low-density lipoprotein cholesterol and triglycerides. These responses may be associated with the ability of garlic and ginger bioactive compounds to regulate lipid synthesis and fat metabolism. The improvement in high-density lipoprotein concentration observed in supplemented groups may further indicate beneficial effects on lipid transport and metabolism. The reduction in total cholesterol, triglycerides and low-density lipoprotein cholesterol observed in the supplemented groups agrees with C.A. Mbajorgu *et al.* (2025), who reported that garlic influenced lipid profiles in laying quails. Similarly, M.M. El-Kashef (2022) reported improved blood biochemical responses in quail birds fed ginger. The improvement in packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count

observed in the combined ginger-garlic group suggests improved physiological and haematopoietic status of the birds. Higher packed cell volume and haemoglobin concentration may indicate improved oxygen-carrying capacity and better physiological condition, while increased red blood cell count may suggest enhanced erythropoiesis. The elevated white blood cell count observed in garlic-supplemented and combined-treatment groups may reflect improved immune responsiveness and physiological adaptation following phytochemical supplementation. These findings indicate that garlic and ginger supplementation did not exert adverse effects on blood formation and may instead support normal haematological function. Similar observations were reported by O.I. Olayinka *et al.* (2024), who found that garlic meal influenced haematological parameters and serum biochemical responses in Japanese quails. The variations observed in serum biochemical parameters indicate that dietary garlic and ginger supplementation influenced protein metabolism, nitrogen metabolism, and electrolyte balance in Japanese quails. Garlic supplementation produced the highest total protein concentration, which may suggest improved protein synthesis, nutrient utilisation, or physiological stability. The differences observed in globulin concentration may also reflect altered immune-related protein metabolism among treatments. Urea and creatinine concentrations varied significantly among groups, although the values remained within acceptable physiological ranges, suggesting no obvious adverse effect of supplementation on kidney function. The significant differences observed in sodium and potassium concentrations indicate that the dietary treatments may have influenced electrolyte regulation and metabolic balance. The variations observed in serum biochemical parameters are consistent with the report by O.I. Olayinka *et al.* that

garlic meal affected that garlic meal affected serum biochemical parameters in Japanese quails and M.M. El-Kashef (2022) also reported that ginger supplementation influenced blood biochemical responses in quail birds.

Conclusions

The findings of this study demonstrated that dietary supplementation with ginger, garlic, and their combination positively influenced the reproductive performance, embryogenesis, antioxidant status, immune response, lipid profile, haematological indices, and serum biochemical parameters of Japanese quails. Fertility percentage and reproductive capacity were significantly improved ($P < 0.05$) in the supplemented groups compared with the control group, although hatchability percentage was not significantly affected among treatments ($P > 0.05$). Embryonic crown-rump length significantly increased ($P < 0.05$) in birds fed diets containing ginger and garlic, indicating improved embryonic growth and development, whereas embryonic weight showed no significant difference among treatments.

The antioxidant results revealed significant increases ($P < 0.05$) in total antioxidant capacity in supplemented groups, particularly in birds administered ginger and the combined ginger-garlic diets. Total oxidant status varied significantly among treatments, while oxidative stress index values remained relatively stable, suggesting maintenance of oxidative balance. Significant improvements ($P < 0.05$) were also observed in serum immunoglobulin concentrations, indicating enhanced humoral immune response in supplemented birds.

Also, the dietary supplementation significantly improved ($P < 0.05$) haematological parameters including packed cell volume, haemoglobin concentration, red blood cell count, and white blood cell count, reflecting improved physiological and immune status of the birds. Serum biochemical and lipid profile analyses showed significant reductions ($P < 0.05$) in total cholesterol, triglycerides, and low-density lipoprotein cholesterol, while beneficial effects were also observed on protein metabolism and electrolyte balance.

In conclusion, the study confirmed that ginger and garlic, particularly when combined at 20 g per kg of feed each, can serve as effective natural PFAs for improving reproductive performance, physiological stability, antioxidant defence, and health status of Japanese quails. Further studies should evaluate the effects of dietary ginger and garlic supplementation on the growth performance, survivability, physiological status, immune response, and post-hatch development of chicks produced from supplemented Japanese quail breeders. The combined supplementation of ginger and garlic showed improved overall physiological responses, and it is recommended as a nutritional strategy for improving the health and productivity of Japanese quails.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Вплив введення часнику (*Allium sativum*) та імбиру (*Zingiber officinale*) на репродуктивні показники, ембріогенез, фізіологічні параметри та оксидативний стрес у японських перепелів

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Анотація. Метою цього дослідження було вивчити вплив введення часнику (*Allium sativum*) та імбиру (*Zingiber officinale*) на ембріогенез, фізіологічні параметри та оксидативний стрес у японських перепелів. Використовувалися чотири раціони: контрольний та раціони, збагачені часником, імбиром та їх комбінацією. Загалом 180 несучих птахів були випадково розподілені на чотири групи з трьома повтореннями по 15 птахів у кожному. Було зібрано 480 яєць для дослідження ембріогенезу після чотиритижневого періоду годування експериментальними раціонами. Дані аналізувалися методом однофакторного дисперсійного аналізу (ANOVA) у SPSS. Відсоток заплідненості та репродуктивна здатність значно підвищилися у японських перепелів, що отримували добавки, а комбінація імбиру та часнику забезпечила вищий відсоток вилуплення життєздатних яєць. Усі обробки призвели до значного збільшення довжини «crown-rump» ($P < 0,05$), тоді як вага ембріонів залишалася подібною у всіх групах. Значне покращення спостерігалось у загальній антиоксидантній здатності птахів, які отримували імбир, часник або їх комбінацію, хоча показники індексу оксидативного стресу статистично не відрізнялися між групами ($P > 0,05$). Рівень IgG у сироватці підвищився після застосування часнику ($P < 0,05$), тоді як рівень IgE значно підвищився після введення імбиру, а комбінація імбиру та часнику сприяла підвищенню рівня IgM ($P < 0,05$). Загальний холестерин значно знизився у сироватці крові японських перепелів, що отримували комбінацію імбиру та часнику. Комбінація імбиру та часнику також покращила гематологічні показники. Введення часнику спричинило значне підвищення ($P < 0,05$) у сироватці крові вмісту загального білка, тоді як інші показники залишалися подібними. Отже, імбир та часник позитивно вплинули на заплідненість, ріст ембріонів, імунітет та антиоксидантний захист у японських перепелів, підтримуючи їх використання як безпечних природних кормових добавок

Ключові слова: фітогенна добавка; відсоток вилуплення; гуморальний імунітет; антиоксидантна здатність; метаболізм ліпідів; гематологія; біохімія сироватки



Morphological features of the kidneys in 2-4-month-old Wistar rats

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Abstract. The relevance of the proposed study is related to the wide distribution of Wistar rats in veterinary and biomedical research, while the anatomy and microanatomy of their kidneys at 2-4 months of age are not sufficiently investigated. This study aimed to determine the characteristics

Suggested Citation:

Lisova, V., Bokotko, R., Gębarowski, T., Dymko, R., & Zhukovskiy, M. (2026). Morphological features of the kidneys in 2-4-month-old Wistar rats. *Ukrainian Journal of Veterinary Sciences*, 17(2), 57-74. doi: 10.31548/veterinary2.2026.57.

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of the anatomical and microscopic structure of the kidneys in Wistar rats of the specified age. Anatomical dissection, macroscopic examination of the kidneys and histological analysis of their structural elements were performed for the implementation of the aim of the study. The kidneys of both male and female Wistar rats of 2, 3, and 4 months of age exhibited the typical structure of the organ, including its dark red colour, bean-shaped form, fibrous connective tissue capsule, and division into cortical and medullary regions. It has been established that the cortical and medullary areas of the kidney have characteristic structural features (such as medullary rays, kidney pyramids, and kidney columns). Within the kidneys, the number of mesangial cells within the renal corpuscles was variable, as were the diameters of the glomerular capillaries; those corpuscles that contained fewer mesangial cells had more dilated capillaries and more blood within their corpuscles. In the proximal convoluted tubules, the nuclei of epithelial cells were often shifted to the luminal surface; the lumen of these tubules often contained proteinaceous masses. The distal convoluted tubules had a more elongated shape, the nuclei of the epithelial cells were often located in the centre of the cells, and the proteinaceous masses accumulated in the lumen did not cause narrowing of the distal tubule lumen. All the collecting duct system tubules consisted of simple cuboid epithelium cells; their cytoplasm was light, and the nuclei were predominantly central. The results obtained can be used in practical experiments in the morphological studies and applied in such disciplines as comparative anatomy, histology, embryology, and veterinary medicine

Keywords: renal corpuscles; mesangiocytes; proximal convoluted tubules; distal convoluted tubules; collecting ducts; cortex; medulla

Introduction

The relevance of the study presented in this study is associated with the fact that Wistar rats are some of the most common types of laboratory animals that are utilised in biological, medical, and veterinary research. In order to understand the results of the experiments that are performed upon these animals, it is first necessary to understand the anatomy and histology of their organs. First and foremost, the kidneys are one of the key organs responsible for maintaining homeostasis and eliminating metabolic waste products. Despite the widespread use of Wistar rats in research, information on the structure of their kidneys is insufficiently systematised and has not provided a comprehensive understanding of the structure of the nephron and its components. Based on the above, a study of the anatomy and microscopic features of the kidneys of Wistar rats was

carried out in order to ensure the appropriate use of this model in future experimental studies. According to A. Domínguez-Oliva *et al.* (2023), animal models are extensively utilised in contemporary biological and medical research to explore the course of pathological processes, evaluate the impact of diverse factors on organisms, and verify the efficacy of therapeutic and prophylactic strategies at the preclinical phase. P. Krubaa & P.S. Yogitha (2024) indicated that the rat is a prominent animal among laboratory animals that is a valuable model due to the possibility of strict control over the genetic and environmental parameters, the relatively large size of the body, ease of invasive manipulations, and a high level of reproducibility of results. In addition, according to S. Patel *et al.* (2024), Wistar rats are one of the most widespread experimental animals in the field of pharmacology,

toxicology, physiology, and biology; they are also a convenient model for obtaining reference values of haematological and biochemical parameters required for the accurate assessment of experimental changes.

The kidney is one of the key organs in all vertebrates, a paired organ that performs the functions of blood filtration and the excretion of metabolic end products, and regulates the water-salt balance and homeostasis in the body. In this regard, the kidneys are one of the target organs in experimental models with the use of toxic agents, metabolic, vascular, and other factors. Much attention has been paid in modern research to studying functional status, the morphological state of the kidney structures in different conditions of the experiment. In a study of water balance, the levels of urinary excretion of some biomarkers, and kidney histology in the Wistar rat, A.C. Ibezute & O.D. Igigie (2024) showed the preservation of kidney architecture without pronounced disturbances. In a study on gentamicin-induced nephrotoxicity, A.I. Matouk *et al.* (2023) found that the most vulnerable structures of the kidney were the tubules. According to R. de Miguel *et al.* (2025), who systematised post-mortem morphological changes of kidneys in Wistar Han rats, the distal convoluted tubules and the inner stripe of the outer medulla are among the most sensitive zones.

The international scientific literature has also described morphological alterations in the kidneys of Wistar rats under the influence of various damaging factors. S.A. Kehinde *et al.* (2025) established that polyethylene microplastics caused impaired renal function and alterations in renal histoarchitecture. C.G.F. Freire *et al.* (2025) demonstrated that exposure to cigarette smoke was accompanied by pronounced morphological changes in the renal tissue of rats of this strain. L. Fedoniuk *et al.* (2025) analysed the morphofunctional features of nephrons under conditions of cellular

dehydration and during periods of adaptation and readaptation, concluding that nephron structural changes under these conditions were substantial and required a prolonged recovery period. Thus, contemporary studies have provided evidence of the high sensitivity of the kidneys in Wistar rats to various experimental factors and confirmed the important role of individual renal structures in the development of morphological responses. At the same time, analysis of the literature demonstrated that most recent studies have focused either on the functional state of the kidneys or on alterations in specific renal structures under experimentally modified physiological conditions. There is a lack of systematic and detailed descriptions in the literature of the anatomical and microscopic structure of the kidneys of Wistar rats as a whole, taking into account the characteristics of the parenchyma, nephrons and collecting duct system in young animals. This applies in particular to a comprehensive description of the renal corpuscles, proximal and distal convoluted tubules, the loop of Henle, and the collecting duct system with an account of their interconnection. Therefore, this study aimed to investigate the anatomical and microscopic features of kidney structures in the young laboratory Wistar rats (2-4 months) with detailed attention to the morphological features of their parenchyma, nephrons and collecting duct system.

Literature Review

The anatomical and microscopic structure of cat, dog, and large mammal kidneys is well-documented. In these species, the kidneys are generally kidney-shaped or bean-shaped. The parenchyma consists of cortical and medullary sections, creating cone-shaped renal lobules. The apices of the lobules directed into the interior of the kidneys, at their concave surface, lead to the entrance of urine into minor calyces that eventually combine into major calyces

that empty into the renal pelvis. R. Baymuradov (2026) noted that the minor and major calyces, together with the renal pelvis, are the elements that compose the renal sinus. At the microscopic level, the functional unit of the kidney is a nephron, a structure composed of a series of successive parts merging into one another. The nephron carries out all the functions characteristic of the kidney. These functions are the excretion of metabolic products of blood and the regulation of blood volume, blood pressure, blood pH, as well as the levels of electrolytes and metabolic byproducts in the serum. The main function of the nephron is the formation of urine, which is eliminated through the urinary tract. Nephron performs three relatively simple procedures, namely filtration, excretion, and resorption. Filtering is carried out by the renal corpuscle, from where nephrons begin to arise. Here, components of the blood plasma pass through a filter of capillaries into the cavity, and the initial formation of urine takes place. According to the observations of H.R. Jacobson (1981), the renal corpuscle is a capsule, consisting of a double-walled capsule, containing a glomerulus of blood capillaries. The glomerulus receives blood from the afferent arteriole and drains it out through the efferent arteriole. The diameter of the efferent arteriole is smaller than that of the afferent arteriole. As a result, increased hydrostatic pressure is observed in the glomerular capillaries, causing water and soluble substances (blood plasma components) to filter into the cavity of the renal corpuscle capsule. It has been shown by A. Madrazo-Ibarra & P. Vaitla (2023) that only about 1/5 of the plasma volume entering the glomerular capillaries can penetrate the glomerular wall and pass into the capsule space. The filtration of the components of the blood plasma through the wall of the renal corpuscle's capsule is regulated by the renal filtration

barrier. This barrier consists of three morphological components. The first of these components is formed by the endothelial cells of the glomerular capillaries. These endothelial cells contain numerous pores referred to as fenestrae. The endothelial cells of the glomerular capillaries are, therefore, referred to as fenestrated endothelial cells. According to the study by N.C. Finch *et al.* (2023), the fenestrae of the fenestrated endothelial cells of the glomerular capillaries are not covered by diaphragms. The diameter of the fenestrae allows for the passage of plasma substances, including proteins.

According to X. Mou *et al.* (2024), the second morphological component of the renal filtration barrier is the basement membrane of the glomerular capillary endothelium. This basement membrane consists of three layers. The layer directly adjacent to the endothelial cells is known as the inner thin lamina, which prevents the passage of molecules owing to its negative charge. In the opinion of K. Ebefors *et al.* (2021), the middle layer of the glomerular capillary endothelial basement membrane consists of bundles of collagen fibres forming a mesh-like structure. This layer limits the size of molecules passing through the basement membrane (it blocks the passage of molecules with a molecular weight greater than 5,800 kDa). D. Chen *et al.* (2024) demonstrated that the third, outer layer of the basement membrane is referred to as the outer thin lamina. This layer restricts the passage of substances through the basement membrane in the same way that the first layer of the basement membrane does. This outer thin lamina is adjacent to the third component of the filtration barrier. The third component of the renal filtration barrier consists of epithelial cells, known as podocytes. These podocytes have long cytoplasmic processes, known as podocyte foot processes, that completely envelop the glomerulus. One of the barriers preventing

the passage of negatively charged molecules, such as serum albumins, through the filtration diaphragm within the pores between podocyte foot processes is the negative charge of the podocyte cell surface, which is covered by a negatively charged glycocalyx. According to the findings of J. Cunanan *et al.* (2025), these foot processes of the podocytes allow for the regulation of the filtration of proteins that exit the lumen of the glomerular capillaries and enter the cavity of the renal corpuscle's capsule. Damage to the filtration diaphragm or to the podocytes themselves results in the filtration of large quantities of proteins into the renal corpuscle capsule cavity, resulting in proteinuria. Podocytes became not only a key component of the kidney's filtration barrier, but they also performed another vital function. Through the control of filtration slit width, the podocytes control the glomerular filtration rate, which represents the amount of filtered blood in all the renal corpuscles. Authors J.F. Bertram *et al.* (2025) state that this parameter has become the most important indicator of the functioning of the kidneys, as a decrease in the normal level of glomerular filtration is generally indicative of the presence of renal failure. The kidney is a complexly organised organ, whose nephron, glomerular filtration barrier and tubular apparatus are responsible for maintaining fluid-electrolyte homeostasis, performing filtration of blood plasma, reabsorption and excretion of waste products. Thus, the interaction of podocytes, mesangial cells, tubular cells, and the collecting system regulates the filtration capacity and the urinary concentration. This is why the morphological evaluation of nephrons in conjunction with renal functional parameters has become the basic tool for interpreting the changes of the water-electrolyte balance, urinary parameters, and the microscopic picture of the kidney in rats under experimental conditions.

Materials and Methods

The experiments were performed at the educational, scientific, and production Clinical Centre Vetmedservice of the NULES of Ukraine between March and May 2026, after which the harvested kidneys were examined and the results analysed. Eighteen sexually mature Wistar rats of both genders were used in the study: 6 rats aged 2 months (3 males and 3 females), 6 rats aged 3 months (3 males and 3 females) and 6 rats aged 4 months (3 males and 3 females). The animals were kept in standard polycarbonate cages under conditions of standard maintenance of the microclimate (temperature 22°C-24°C, relative humidity 50%-60%, 12-hour light/12-hour dark photoperiod), with standard pelleted feed and drinking water available at any time. All the experimental animals underwent daily observation (monitoring of the general clinical status, behaviour, feed and water intake) throughout the experimental period. At the end of the experiment, the animals were subjected to human euthanasia by the inhalation of CO₂ in the absence of prior gas filling of the exposure chamber at a flow rate of 30%-70% of the chamber volume per minute, followed by the secondary use of physical methods to confirm that the animals were dead, such as decapitation. All procedures and euthanasia were carried out in accordance with the requirements and provisions of the European Convention for the Protection of Vertebrate Animals used for Research and other Scientific Purposes (1986) and the Law of Ukraine No. 3447-IV (2006). Approval for the study was obtained from the Bioethics Commission of the NULES of Ukraine for the use of animals in scientific research (No. 045/2025, dated 26 June 2025). During animal housing and experimental procedures, the scientific and practical recommendations of Y. Kozhemiakin *et al.* (2002) concerning work with laboratory animals were followed.

A post-mortem examination of all rats was performed via complete evisceration. To perform this procedure, the skin was incised from the angle of the mandible to the pubic bone, and the skin was separated from the underlying tissues. The muscles of the anterior abdominal wall were dissected in the median line, and all muscles surrounding the pharynx, larynx, the cervical part of the pharynx, the thyroid gland, and the cervical part of the trachea were dissected to free these organs. The thoracic cavity was opened by a sternal approach. The thoracic cavity was opened via severance of the ribs and costal cartilages along all ribs, and removal of the sternum. After all body cavities were opened, the location of the internal organs was examined and photographed. Subsequently, all internal organs were removed as a single organ complex, beginning with the tongue, followed by the organs of the neck, thoracic cavity, gastrointestinal tract, and pancreas, while transecting the supporting structures of these organs. The location of the spleen, liver, and kidneys was examined, photographed, and the organs of the reproductive system in females (ovaries, oviducts, uterus, vagina, and external genitalia) were also checked. The spleen, liver, and kidneys were removed, whereas in females, the organs of the reproductive system (ovaries, oviducts, uterus, vagina, and external genitalia) were removed together. The external surfaces of the kidneys were inspected and recorded with a focus on size, outline, colour of the surfaces and state of the capsule. A longitudinal incision through the midline was done, and the kidneys were investigated and photographed in the section, with particular attention being paid to the features of the structural organisation of the cortex and medulla, the border between these tissues, the renal papillae, renal calyces and renal pelvis. After the study of the topographical anatomy

of the experimental rat kidneys, tissue samples were taken from each kidney, in a manner to encompass all the structures, from the renal cortex to the renal pelvis. Fragments were fixed in a 10% solution of formalin (pH 7.2-7.4) for 7 days and then dehydrated using ethanol (70°, 80°, 95°, and 100°). The pieces were left in each of the ethanol solutions for 24 hours. The fragments were cleared in chloroform and embedded in paraffin at +58°C. Histological sections 6-8 µm thick were obtained using a sledge microtome MBS-2 (Med-Tech, Ukraine) and stained with Carazzi's haematoxylin and eosin. All histological preparations were examined under an MS-100X microscope (Micros, Austria) and photographed using an NDPL-2 (2x) photoadapter and a Canon EOS 550D camera (Canon, Japan).

Results and Discussion

The kidneys are one of the key organs of the urinary system of the rat. The structure of the kidney is associated with the physiological processes of the organ, including the formation of urine. Therefore, an investigation of the macroscopic and microscopic structure of the kidneys of Wistar rats is essential to gain an understanding of the morphological norms characteristic of a particular species and age. Special interest is the study of the kidney of sexually mature rats aged 2-4 months, which are most commonly used in experimental biological, morphological and toxicological research. Accordingly, a comprehensive macro- and microscopic examination of the kidneys of Wistar rats was conducted, taking into account their anatomical structure, histological organisation of the parenchyma, nephrons, tubular apparatus, and collecting system. The study found that in Wistar rats aged 2-4 months, as in other strains of rats and, generally, in mammals, the kidneys are located in the retroperitoneal space (Fig. 1).



Figure 1. Anatomical position of the kidney in a sexually mature Wistar rat (female), 3 months of age

Note: macroscopic specimen, kidney indicated by arrow; 1 – small intestine; 2 – caecum; 3 – rectum; 4 – stomach; 5 – spleen; 6 – pancreas

Source: authors' photo

There were no morphological differences in the kidneys of males and females of this age. At the same time, the kidneys of Wistar laboratory rats aged 2-4 months were dark red in colour (Fig. 2) and bean-shaped, with convex and concave surfaces.

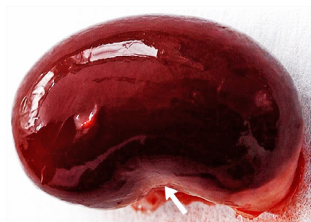


Figure 2. External appearance of the kidney in a sexually mature Wistar rat (male), 2 months of age

Note: macroscopic specimen, renal hilum indicated by arrow

Source: authors' photo

On the concave surface of the kidneys, there is a depression known as the renal hilum. On this part of the kidney, the renal artery enters and the renal vein and ureter exit. In the hilum, there is also adipose tissue and lymph nodes. Externally, the kidneys are covered by a fibrous connective tissue capsule, which in turn is surrounded by a fatty capsule. Ventrally and

laterally, the fatty capsule is enclosed by the peritoneum, while dorsally it is covered by the transverse fascia. A cross-section of the kidneys in 2-4-month-old Wistar rats shows that the parenchyma of this organ is composed of two parts: the cortex, located in the peripheral region of the kidney, and the medulla, situated in the central region (Fig. 3).



Figure 3. Kidney of a sexually mature Wistar rat (male), 4 months of age, in cross-section

Note: macroscopic specimen: 1 – cortex; 2 – medulla; 3 – renal lobule; 4 – renal column; 5 – minor calyx; 6 – major calyx; 7 – renal sinus; 8 – renal pyramids

Source: authors' photo

The cortex and medulla form cone-shaped renal lobules, each of which gives rise to renal pyramids. The renal columns (Bertin columns), which represent an outgrowth of cortical substance, lie between the pyramids. The cortical substance also includes medullary rays, in each of which are many tubules that pass into a common excretory tube. The upper part of the pyramids is the renal papilla. Slightly above the papillae, there were small cavities (the minor renal calyces) where the urine from the papillae entered. Further down the urinary tract, the minor calyces merged into the major calyces, opening into the renal pelvis. The renal pelvis and the calyces make up the renal sinus. The histological examination of the kidneys of female and male Wistar rats aged 2-4 months revealed no differences in the microscopic structure of the kidneys. On the outer side, the surface of the kidneys is covered with mesothelium, which consists of a single layer of

significantly flattened cells with elongated, spindle- or rod-shaped nuclei and a large amount of cytoplasm (Fig. 4).

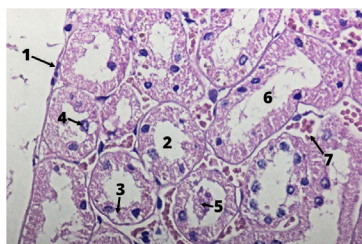


Figure 4. Cortex of the kidney in a sexually mature Wistar rat (female), 2 months of age
Note: 1 – renal capsule; 2 – proximal convoluted tubule; 3 – cytoplasmic accumulation of fluid in epithelial cells of the proximal convoluted tubule; 4 – displacement of the nucleus into the lumen of the proximal convoluted tubule; 5 – proteinaceous material in the lumen of the proximal convoluted tubule; 6 – distal convoluted tubule; 7 – blood vessel of the interstitium. Carazzi's haematoxylin and eosin, $\times 400$
Source: authors' photo

According to W. Kriz & B. Kaissling (2008), two main morphological elements can be distinguished microscopically in the mammalian kidney: the “urinary” and the “vascular” compartments. The morphological and functional unit of the kidney is a nephron, which fulfils all functions of the kidney. Each kidney in rats contains, depending on the breed and age of the animal, 30,000-40,000 nephrons, each of which is divided into the following sequential segments: the renal corpuscle, the proximal convoluted tubule, the loop of Henle (comprising descending and ascending limbs), the distal convoluted tubule, and the collecting duct system. Based on the location of the renal corpuscles and the length of the loop of Henle, nephrons in the kidney are classified into cortical and juxtamedullary types. Renal corpuscles of both cortical and juxtamedullary nephrons are found in the renal cortex substance, but the corpuscles of cortical nephrons are located in the superficial layer of the cortex, while renal corpuscles of the juxtamedullary nephrons

are located adjacent to the medulla (Fig. 5). Cortical nephrons predominate in the kidney. According to A.M. Hall (2025), juxtamedullary nephrons account for only 15% of the total nephron population.

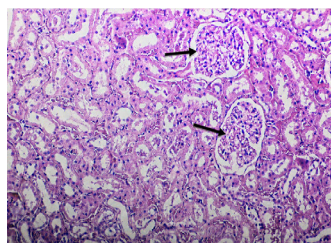


Figure 5. Renal corpuscles of cortical nephrons in the kidney of a sexually mature Wistar rat (female), 2 months of age
Note: renal corpuscles of cortical nephrons indicated by arrows. Carazzi's haematoxylin and eosin, $\times 200$
Source: authors' photo

In cortical nephrons, the loop of Henle extends into the medulla near the corticomedullary junction. In juxtamedullary nephrons, the loop of Henle is located in the deeper regions of the renal medulla. Accordingly, the loop of Henle in cortical nephrons is shorter, whereas in juxtamedullary nephrons it is considerably longer. As noted by S. Bachmann *et al.* (1986) and T. Blanc *et al.* (2021), the longer loop of Henle in juxtamedullary nephrons establishes a hyperosmotic gradient, which facilitates the formation of concentrated urine. Renal corpuscle is the initial part of the filtering of nephrons in Wistar rats' kidneys, 2-4 months of age. In turn, the renal corpuscle is formed by a tuft of blood capillaries (known as the glomerulus of the renal corpuscle), which is surrounded by the capsule of the renal corpuscle (Fig. 6). At the same time, the renal corpuscle is formed from two layers: the outer capsule layer (parietal), which does not take part in filtration processes, and the inner capsule layer (visceral) that covers the glomerulus of renal corpuscle externally. Between these two layers was a cavity known

as the lumen of the renal corpuscle capsule. Primary urine is filtered from the glomerulus in the capsular space, then moves from there into the proximal convoluted tubule.

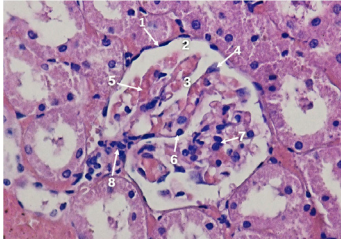


Figure 6. Renal corpuscle of a sexually mature Wistar rat (male), 4 months of age

Note: 1 – cells of the parietal layer of the renal corpuscle capsule; 2 – capsular space of the renal corpuscle; 3 – space between the loops of the glomerular capillary tuft; 4 – podocyte; 5 – blood-filled glomerular capillary; 6 – endothelial cell of the glomerular capillary; 7 – small number of intraglomerular mesangial cells; 8 – extraglomerular mesangial cells. Carazzi's haematoxylin and eosin, $\times 400$

Source: authors' photo

The parietal layer of the renal corpuscle is composed of a single layer of epithelial cells of simple squamous epithelium. The visceral layer of the renal corpuscle capsule is formed by the podocytes – epithelial cells positioned externally on the glomerulus's basement membrane. There are intercellular slits between the long (pedicle processes) processes of the podocytes, which surround the entire glomerulus and are about 8 nm in diameter. It is through these pores that the blood components pass and are filtered into the renal corpuscle capsule space. Filtration diaphragms, situated in the interstices between podocyte projections, control this filtering level. Diaphragms are composed of multiple proteins embedded on the surface of the foot processes of podocytes. These diaphragms allow a filtrate of proteins of about 30 kDa molecular mass to pass, but given the negative charge of both the basement membrane of a glomerular capillary and

the surface of podocytes covered by glycocalyx, there is an additional mechanism to resist the movement of negatively charged molecules (e.g. serum albumin). Therefore, the composition of blood filtrate that enters the capsular space of the renal corpuscle (primary urine) includes all substances found in blood plasma, excluding plasma proteins (Yoshimura & Nishinakamura, 2019; Cunanan *et al.*, 2025).

In the renal glomeruli of laboratory rats, Wistar (2–4 months of age), blood capillaries whose walls comprise endothelial cells with a typical microscopic structure are the structural foundation (Fig. 6). These cells rest on a thick basement membrane. Overall, the renal filtration barrier located within the renal corpuscle is composed of three components: the endothelium of the glomerular capillaries, the basement membrane of the glomerular capillary endothelium, and the filtration slits of the podocytes. Within the glomeruli, between the blood capillaries, lies the interstitial component of the glomerulus – the mesangium – which consists of the mesangial extracellular matrix and cells (intraglomerular mesangio-cytes), which surround the blood capillaries in each glomerulus (Fig. 6). These cells cover approximately 30% of the capillary surface externally and perform three main functions: providing structural support to the glomerulus, phagocytosis, and regulation of filtration processes within the renal corpuscle. According to K. Ebefors *et al.* (2021), regulation in the renal corpuscle is also indirectly provided by the contractile properties of intraglomerular mesangial cells, which affect blood flow in the glomerular capillaries. The number of mesangial cells in laboratory rats, Wistar (2–4 months of age), was different for individual glomeruli of the same kidney. This was closely related to other morphological changes in renal corpuscles. In the renal corpuscles with a smaller number of intraglomerular mesangi-

al cells (Fig. 6), capillaries in the glomerulus were much more dilated than in those that had a higher number of intraglomerular mesangial cells (Fig. 7) and were also fuller of blood.

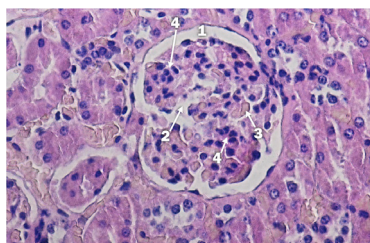


Figure 7. Renal corpuscle of a sexually mature Wistar rat (male), 4 months of age

Note: 1 – capsular space of the renal corpuscle; 2 – space between loops of the glomerular capillary tuft; 3 – small amount of blood within a glomerular capillary; 4 – high number of intraglomerular mesangial cells. Carazzi's haematoxylin and eosin, $\times 400$

Source: authors' photo

Further, in the renal corpuscles with a lower number of mesangial cells, there was a larger interval between the loops of the capillary tuft in the glomerulus. This reflected a different intensity of glomerular filtration in each of the renal corpuscles. In the renal corpuscles of laboratory rats, Wistar (2-4 months of age), in addition to intraglomerular mesangial cells, there were also found extraglomerular mesangial cells, which formed part of the juxtaglomerular apparatus. In a single nephron in laboratory rats, Wistar (2-4 months of age), the proximal convoluted tubule began in the outer parietal layer of the renal corpuscle capsule and continued directly into the renal corpuscle capsule (Fig. 8).

A.M. Hall (2025) and M.P. Hoenig *et al.* (2025) stated that usually such tubules have a rounded shape. They are formed by a relatively thick basement membrane on which a single layer of cuboidal epithelial cells is arranged. On the luminal side, these cells possess a striated border, which increases the

absorptive surface area in this segment of the nephron. About 60%-70% of the salts and water in the primary urine are reabsorbed in the proximal convoluted tubule, together with all of the organic substances, in particular amino acids. For this reason, the cytoplasm of the epithelial cells of the tubules often looks foamy and vacuolated with large vacuoles, due to the abundant fluid in them. This is evidence of the intense activity of the process of reabsorption in this part of the nephron of Wistar rats aged 2-4 months. Due to the extensive absorption of substances by the epithelial cells of the proximal convoluted tubule, other morphological changes seen in the cells in Wistar rats aged 2-4 months post-natal age range include the shift of the nuclei of epithelial cells towards the lumen of the tubules and the appearance in the lumen of proteinaceous material, which in part occludes the lumen in a number of segments of the proximal convoluted tubule. Analysis of the morphology of the cortical substance of the kidney in sexually mature female Wistar rats aged 3 months showed clearly recognisable convoluted tubules and a descending limb of the loop of Henle that had maintained its structure, indicating a normal organisation of the nephron at this stage of postnatal development (Fig. 9).

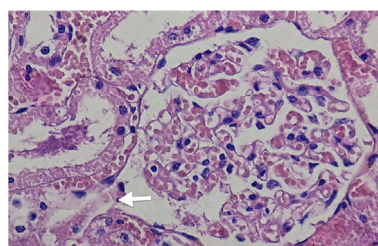


Figure 8. Renal corpuscle of a sexually mature Wistar rat (male), 4 months of age

Note: the origin of the proximal convoluted tubule from the outer layer of the renal corpuscle capsule is indicated by an arrow. Carazzi's haematoxylin and eosin, $\times 400$

Source: authors' photo

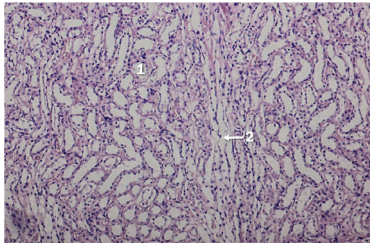


Figure 9. Renal cortex of a sexually mature Wistar rat (male), 3 months of age

Note: 1 – convoluted tubules; 2 – descending limb of the loop of Henle. Carazzi's haematoxylin and eosin, $\times 100$
Source: authors' photo

The loop of Henle continues from the proximal convoluted tubule and is subdivided into descending and ascending parts. In Wistar rats 2-4 months of age of laboratory origin, the descending limb of the loop of Henle was seen on stained slides with haematoxylin and eosin as a slightly serpentine tubule whose wall consisted of a distinctly flattened simple squamous epithelium, lying on a fairly thin basement membrane, and resembling straight renal vessels. Its epithelial cells had elongated nuclei, very similar to those in the endothelium of blood vessels. However, the descending segment of the Henle loop was easily distinguished from straight renal vessels by the absence of blood cells in its lumen (Fig. 10).

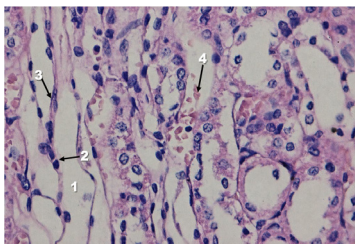


Figure 10. Descending limb of the loop of Henle in the kidney of a sexually mature Wistar rat (female), 3 months of age

Note: 1 – lumen of the descending limb of the loop of Henle; 2 – epithelium of the descending limb of the loop of Henle; 3 – basement membrane of the epithelium of the descending limb of the loop of Henle; 4 – erythrocytes in the lumen of a blood vessel. Carazzi's haematoxylin and eosin, $\times 400$

Source: authors' photo

The ascending limb of the Henle loop, like the descending limb, was lined with simple squamous epithelium and was clearly distinguishable from blood vessels (Fig. 11). On histological sections, its lumen was most often narrow and sometimes moderately dilated, and did not contain any blood cells. The epithelial cells had elongated and clearly stained nuclei, arranged parallel to the surface of the basement membrane and were flat with a thin layer of cytoplasm. The wall of the loop of Henle appeared thin and uniform. There was no marked cellular infiltration. In contrast to the vessels, there were no blood cells in its lumen, and the cells in the wall had an orderly arrangement. In these aspects, these elements facilitate the differentiation between the loop of Henle and the capillaries or smaller vessels of the renal medulla.

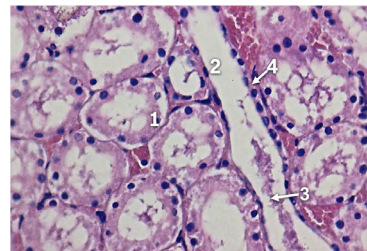


Figure 11. Ascending limb of the loop of Henle in the kidney of a sexually mature Wistar rat (male), 3 months of age

Note: 1 – convoluted tubules; 2 – lumen of the loop of Henle; 3 – proteinaceous material in the lumen of the loop of Henle; 4 – epithelial cells of the ascending limb of the loop of Henle. Carazzi's haematoxylin and eosin, $\times 400$
Source: authors' photo

A.-A. Marcoux *et al.* (2022) noted that, in the loop of Henle of the nephron, 25% of the ions and 20% of the water in the renal corpuscle are reabsorbed. The loop of Henle subsequently transitions into the distal convoluted tubule. In Wistar rats aged 2-4 months, the distal convoluted tubules are clearly differentiated from the proximal convoluted tubules –

alongside which they reside within the renal cortex – owing to their distinct morphological characteristics. Compared to the round proximal convoluted tubules, the distal convoluted tubules seemed more elongated, oval, and of irregular shape. The nuclei of the epithelial cells of the distal convoluted tubules were large, round, and centrally located within the cytoplasm. Nuclear displacement of epithelial cells, characteristic of the proximal convoluted tubules, was not observed. Proteinaceous material was also present in the lumen of the distal convoluted tubules; however, unlike in the proximal convoluted tubules, it did not lead to luminal obstruction. The cytoplasm of the epithelial cells of the distal convoluted tubules, similarly to that of the proximal convoluted tubules, had a foamy appearance and formed a striated border on the luminal surface. However, unlike in the proximal convoluted tubules, the cytoplasm of the epithelial cells of the distal convoluted tubules formed basal infoldings, which increase the surface area of this part of the cell membrane for the placement of ion pumps and transporters. As in the proximal convoluted tubules, the distal convoluted tubules were lined by a single layer of cuboidal epithelial cells resting on a relatively thick basement membrane.

The distal convoluted tubules continued into the collecting duct system. In Wistar rats aged 24 months, the different segments of the collecting duct system (connecting tubules, cortical collecting ducts, outer medullary collecting ducts, inner medullary collecting ducts, and Bellini's ducts formed by the fusion of inner medullary collecting ducts) exhibited a uniform microscopic structure in the histological preparations examined. None of these sections was a straight tube; instead, they were sinuous, and some of the connecting tubules were arched in shape. From the morphological

point of view, all the sections of the collecting duct system were formed by a single layer of cubic epithelial cells on a basement membrane (Fig. 12). These cells had a light-staining nucleus of an average size, usually in the middle of the cell, and lightly stained cytoplasm.

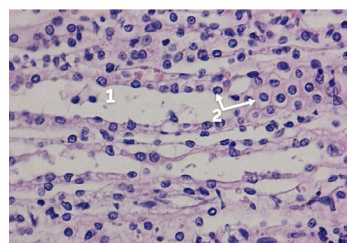


Figure 12. Renal medulla in a sexually mature Wistar rat (male), 2 months of age

Note: 1 – lumen of the inner medullary collecting duct; 2 – epithelium of the inner medullary collecting duct. Carazzi's haematoxylin and eosin, $\times 400$

Source: authors' photo

The wall of the renal pelvis in Wistar rats aged 2-4 months was lined with stratified epithelium (Fig. 13) on the side of the renal pelvis lumen. Three cellular layers could be seen in the stratified epithelium. The base layer consisted of a polymorph population of cells of different sizes and shapes, with a small amount of cytoplasm in a thin band and an oval, round, and elongated shape of nuclei, and some degree of chromatin condensation was revealed. This polymorphism reflects the processes of cell division. In the intermediate layer, the cells seemed to be more homogenous. They were more or less the same size and round or oval in shape, with a greater amount of cytoplasm and an oval or round nucleus with less condensed chromatin. The cells of the superficial layer, in direct contact with the cavity of the renal pelvis, were flattened cells, usually elongated along the general surface of the epithelium, with elongated and oval nuclei.

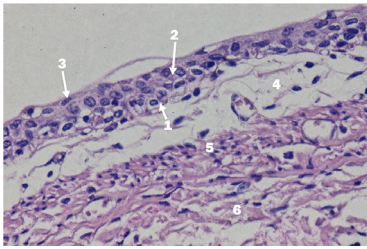


Figure 13. Wall of the renal pelvis in a sexually mature Wistar rat (male), 3 months of age

Note: 1 – cells of the basal layer of the epithelium; 2 – cells of the intermediate epithelial layer; 3 – cells of the superficial epithelial layer; 4 – loose fibrous connective tissue; 5 – smooth muscle cells; 6 – loose fibrous connective tissue. Carazzi's haematoxylin and eosin, $\times 400$

Source: authors' photo

Beneath the surface epithelium, there was a layer of loose fibrous connective tissue composed of sparsely distributed fibroblasts and bundles of collagen fibres. Blood vessels were also observed within this layer of the renal pelvis wall. Below this layer lay a layer of smooth muscle cells, beneath which there was again a layer of loose fibrous connective tissue. One of the structural components of the renal corpuscle is the mesangium – the glomerular interstitium, consisting of an extracellular matrix and cells known as mesangial cells (mesangio-cytes). All mesangio-cytes are divided, according to their location and function, into intraglomerular and extraglomerular forms. According to B. He *et al.* (2021), the intraglomerular mesangial cells surround glomerular capillaries, and cover about 30% of their external surface, being responsible for three major functions: structural support of the glomerulus, maintenance of filtration processes, and participation in phagocytosis. Intraglomerular mesangio-cytes produce an extracellular mesangial matrix, composed of type IV collagen, perlecan, fibronectin, and laminin. They also phagocytose immune complexes and cell debris in the

glomerulus, such as fragments of the basement membrane or fragments of mesangio-cytes that have undergone apoptosis. Intraglomerular mesangio-cytes also have contractile properties, being able to contract the glomerular basement membrane and reduce the glomerular surface, decreasing the filtration rate of the renal corpuscle. K. Ebefors *et al.* (2022) reported that, through their processes extending into the lumen of the glomerular capillaries, these cells may also participate in the regulation of serum glucose levels.

M.P. Hoenig *et al.* (2025) reported that extraglomerular mesangio-cytes are located outside the glomeruli in the region of the vascular poles of the renal corpuscles. They are classified as part of the juxtaglomerular apparatus. Urine from the primary formation of each renal corpuscle passes into the renal tubules for further modification. Every renal tubule consists of separate sections, which are differentiated both in structure and function. The proximal convoluted tubule emerges directly from the renal corpuscle and is situated in the cortex. It is lined with simple cuboidal epithelium, the adjacent cells of which are connected by large lateral interdigitating contacts. Consequently, in the microscope, it is difficult to define the boundaries between neighbouring epithelial cells of the proximal convoluted tubule. In this tubule, about 2/3 of salts and water, as well as all organic substances (mainly glucose and amino acids), are reabsorbed.

M. Alamilla-Sanchez *et al.* (2025) described that the basic function of the loop of Henle is to increase the salinity of the interstitium and ensure the concentration of different components of the plasma. D. Pearce *et al.* (2022) reported that the loop of Henle is lined with cells whose cytoplasm contains many mitochondria to provide the energy required for the reabsorption of calcium, sodium and chloride.

After that, the distal convoluted tubule passes through into the collecting duct system, through which water is exchanged along with electrolytes – sodium, potassium and hydrogen ions. M. Alamilla-Sanchez *et al.* (2025) also reported that reabsorption of electrolytes is regulated by aldosterone and antidiuretic hormone. Accordingly, the kidneys of Wistar rats aged 2-4 months were morphologically typical of other mammalian species, with neither macro- nor microscopic structure revealing significant sex-related differences at this age. Their morphological organisation was characterised by a clear distinction between cortical and medullary parts, with both types of nephrons present – cortical and juxtamedullary – in all rats. Renal corpuscles, the tubular system and the collecting system had a characteristic architecture. Their specific features of microscopic structure allowed functional differentiation of all segments of the nephron, providing for filtration, reabsorption, and final processing of urine.

Conclusions

Anatomical and histological examination of the kidneys of sexually mature Wistar rats aged 2-4 months showed that the macroscopical structure of this organ was typical, identical in males and females and compliant with general species-specific organisational features of mammalian kidneys. They demonstrated their typical retroperitoneal position, bean-shaped form, dark-red colour and a clear boundary of the hilum as well as cortex and medulla, pyramids, calyces and renal pelvis, which is evidence of full maturation of organ morphological organisation. At the microscopic level, the kidneys of laboratory rats of the studied age had a typical for other mammalian species morphological organisation with a clearly distinguished cortex and juxtamedulla, and with a number of structural elements including renal corpuscles, proximal and distal convoluted

tubules, loops of Henle, collecting duct system and renal pelvis. The amount of mesangiocytes of intraglomerular capillaries differed in different glomeruli in the same kidney, and the smaller amount of mesangiocytes was accompanied by more dilated capillary loops, a higher blood content in the glomerulus and a wider space between the capillary loops due to lower glomerular filtration intensity. In the proximal convoluted tubules, the functional organisation of epithelium was revealed as evidenced by foamy epithelium cytoplasm with big vacuoles in many cells, displaced towards the tubular lumen, nucleus of the epithelium, and proteinaceous mass with partial obliteration of the tubular lumen observed in a few tubules. The distal convoluted tubules differed in an elongated shape of tubules with a central position of the nuclei of epithelial cells, no lumen obliteration, although with a large quantity of proteinaceous mass in the lumen. All segments of the collecting duct system were represented with simple cuboidal epithelium with pale cytoplasm and the nuclei centrally located in most of the cells. The renal pelvis was characterised by a well-developed wall in the form of a three-layered epitheliumconnective tissue-muscle wall. Further study is recommended in which quantitative estimation of morphometric characteristics of separate nephron elements is carried out, as well as the determination of the correlation between morphological and functional characteristics under physiological conditions and experimentally induced pathological states.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Морфологічні особливості нирок у 2-4-місячних щурів лінії Wistar

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Анотація. Актуальність дослідження зумовлена тим, що щури лінії Wistar широко використовуються у ветеринарних і біомедичних дослідженнях, однак анатомічна та мікроскопічна будова їх нирок у віці 2-4 місяців описана недостатньо. Метою роботи було вивчення особливостей анатомічної і мікроскопічної будови нирок у щурів лінії Wistar зазначеного віку. Для досягнення поставленої мети застосовано анатомічний розтин, макроскопічне дослідження нирок та гістологічний аналіз їх структурних компонентів. Встановлено, що нирки самок і самців щурів лінії Wistar у 2, 3 і 4 місяці мали типову для

цього органу будову – темно-червоний колір, бобоподібну форму, капсулу з волокнистої сполучної тканини та чітке розмежування на кіркову і мозкову речовину. З'ясовано, що кіркова і мозкова речовина формували характерні структурні елементи нирки, зокрема медулярні промені, піраміди та ниркові стовпи. Під час гістологічного дослідження було встановлено, що в різних ниркових тільцях кількість клітин мезангіюму неоднакова, а при меншій кількості внутрішньоклубочкових мезангіоцитів капіляри клубочка були більш розширеними і містили більше крові. Виявлено, що у проксимальних звивистих канальцях ядра епітеліоцитів нерідко зміщені у бік просвіту, а в самому просвіті містилася білкова речовина. Дистальні звивисті канальці мали більш витягнуту форму, їх ядра розташовані центрально, а білкова речовина в просвіті не спричиняла його закупорки. Усі відділи системи збірних канальців вистелені одношаровим кубічним епітелієм зі світлою цитоплазмою та переважно центрально розташованими ядрами. Отримані результати мають практичне значення для проведення експериментальних морфологічних досліджень, а також для порівняльної анатомії, гістології та ветеринарної медицини

Ключові слова: ниркові тільця; мезангіоцити; проксимальні звивисті канальці; дистальні звивисті канальці; збірні канальці; кіркова речовина; мозкова речовина



2026. Volume 17, No. 2 P. 75-91

ISSN 2663-967X;
e-ISSN 2663-9688

Journal homepage: <https://veterinaryscience.com.ua/en>

DOI: 10.31548/veterinary2.2026.75

UDC 636.09:636.2

Received: 06.01.2026 Revised: 10.04.2026 Accepted: 21.05.2026 Published: 28.05.2026

Correction of the clinical and biochemical status of high-producing cows during the transition period

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Abstract. The relevance of this study is determined by the increasing number of diagnosed metabolic diseases in high-yielding cows during the transition period, particularly ketosis, fatty liver disease and their complications, including liver cirrhosis, reproductive dysfunctions and subsequent early culling of cows. Timely measures for preventing metabolic diseases during the transition period are important, as they involve the use of corrective therapy to normalise metabolism and increase productivity. Therefore, this study aimed to investigate the effect of a complex preparation on the clinical and biochemical status of high-producing cows during the transition period. Two groups were formed for the experiment: a control group and an experimental group, with 10 cows in each. During the experiment, general methods of clinical examination of cows were used, including inspection, palpation, percussion and thermometry, as well as biochemical analysis of blood serum parameters, including spectrophotometry and chromatography. These methods made it possible to identify biological markers for assessing changes in the clinical condition and individual metabolic pathways in cows under the influence of the complex preparation. The use of the complex preparation based on biologically active substances led to an increase in blood serum levels of glucose by 25.6%, the total lipoprotein fraction by 55.7%, vitamin A by 35.9% and vitamin E by 2.1 times in cows of

Suggested Citation:

Danchuk, V., Karpovskiy, V., Danchuk, O., Zhurienko, O., & Grafov, O. (2026). Correction of the clinical and biochemical status of high-producing cows during the transition period. *Ukrainian Journal of Veterinary Sciences*, 17(2), 75-91. doi: 10.31548/veterinary2.2026.75.

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the experimental group. It also reduced aspartate aminotransferase activity by 51.3%, the De Ritis ratio by 62.3%, the level of non-esterified fatty acids by 2.16 times and beta hydroxybutyrate by 42.7%. Early identification of the causes of metabolic disorders and pathological changes in the liver of high-producing cows during the transition period, together with the timely preventive use of a complex preparation based on biologically active components, made it possible to prevent the development of secondary diseases, particularly fatty hepatodystrophy, and to reduce economic losses caused by lower milk yield and the culling of cows under the conditions of a specific farm

Keywords: liver; hepatodystrophy; general clinical condition of the organism; biochemical analysis; spectrophotometry; high-performance liquid chromatography; biologically active substances

Introduction

Dairy farming is an important branch of animal husbandry; however, its efficiency is largely limited by the spread of metabolic disorders in high-producing cows, especially during the transition period. At this stage, animals experience the greatest physiological strain owing to the shift from the dry period to intensive lactation. This process is accompanied by a negative energy balance, mobilisation of fat reserves, impaired functional status of the liver and an increased risk of ketosis, fatty hepatodystrophy and other postpartum complications. These pathologies reduce milk productivity, impair reproductive function, increase treatment costs and may lead to the premature culling of animals, creating both a veterinary and an economic problem for dairy farms.

In this context, V. Kolosha (2022) noted that the economic efficiency of dairy farming should be considered in terms of animal reproduction, production intensification and optimisation of product volumes throughout the year. V.V. Vlizlo *et al.* (2021) reported that the high milk productivity of cows on farms largely depends on their health. The average productive lifespan of cows in countries with highly developed dairy farming is 3-4 years. This is considerably shorter than the natural lifespan of dairy cattle. The culling of cows on farms is associated with reduced milk productivity and impaired

reproductive function, which result from the development of various pathologies. The morbidity of high-producing cows on dairy farms is caused by disruptions in the technological processes of housing and feeding. Diseases in cows are especially common during the postpartum period. After calving, dairy cows are often diagnosed with metabolic disorders and lesions of the internal organs. Liver diseases in cows, in particular, are among the most common conditions and occur far more frequently than previously assumed, as these pathologies are either subclinical or present with general and non-specific symptoms.

D. Kibkalo *et al.* (2024) demonstrated that fatty degeneration is one of the leading liver pathologies in cows kept at dairy complexes. This pathology causes substantial economic losses, including the costs of treatment, lost income due to an irreversible reduction in milk productivity, acquired symptomatic diseases and infertility. C. Zhang *et al.* (2023) indicated that the liver is a key organ in the regulation of overall metabolism. Therefore, hormonal status, particularly in high-producing dairy cows, may be reflected in changes in the functional state of the liver, leading to the development of a range of local and systemic inflammatory and degenerative processes. Most often, this is fibrosis, a common pathology in cows with fatty

liver degeneration, which develops as a result of oxidative stress, inflammation and hepatocyte death. In particular, C.A. Risco & P. Melendez (2022) noted that, due to oxidative stress and hepatocyte inflammation, cows become more susceptible to secondary diseases, including ketosis, displaced abomasum, mastitis, retained placenta, metritis, reduced fertility and low milk production.

According to the findings of V.M. Olihevskiy & S.V. Huralaska (2025), metabolic disorders in first-lactation dairy cows impair the functional capacity of hepatocytes by altering their histological structure. In particular, diffuse vacuolisation of the hepatocyte cytoplasm, diffuse necrosis and lymphocytic-macrophage infiltration of the portal tracts were observed with the concurrent development of ketosis and endometritis. In cows with ketosis and hypocalcaemia, extensive hepatocyte vacuolisation, generalised tissue necrosis and mild lymphocytic-macrophage infiltration were recorded. In cases of ketosis and mastitis, marked diffuse vacuolisation of hepatocytes, indicating severe fatty degeneration, moderate diffuse necrosis and accumulation of inflammatory cells were observed, which pointed to focal chronic hepatitis. In cows in the second and third lactations, hepatocyte changes were even more pronounced, with the development of severe hepatitis combined with chronic inflammation and early fibrosis, reflecting a high level of metabolic stress. Thus, the authors indicated substantial morphofunctional changes in the liver under polymorbid pathology in cows, depending on the lactation period and the combination of metabolic diseases.

According to Ye. Mekuriaw (2023), feeding and housing practices, as well as breed differences, may lead to different degrees of negative energy balance in dairy cows. Holstein cows mobilise significantly more body energy at the beginning of lactation than Danish Red and

Jersey cows. Primiparous cows are more susceptible to metabolic stress during the transition period than multiparous cows. Therefore, the duration and severity of negative energy balance in dairy cows depend on their housing conditions. Although negative energy balance is common in highproducing dairy cows and may have consequences ranging from mild to severe, its extent can be minimised through proper feeding and the use of feed additives. Cows that were fed diets with a higher energy value had a better energy balance.

The transition period is extremely important in determining the future health of reproductive dairy cows and milk production. This period lasts from three weeks before calving to three weeks after calving, when the cow moves from the dry period to lactation. As noted by Ö. Kizil & M. Kizil (2023), the transition from pregnancy to a stage accompanied by intensive lactation is very often a critical factor. The welfare and productivity of cows can be substantially improved by identifying the factors that explain their high morbidity during the transition period. A key factor during this period is lipid metabolism in cows, as excessive lipid mobilisation from adipose tissue is associated with a higher incidence of health problems in these animals during the transition period.

This study aimed to determine the effect of an experimental complex preparation on the clinical status and selected aspects of carbohydrate, lipid, vitamin and mineral metabolism in highproducing cows during the transition period.

Literature Review

The most critical stage in dairy farming is the transition period. This is the time when the cow's requirements for nutrients needed for milk synthesis increase rapidly. M. Mezzetti *et al.* (2021) indicated that the rapid increase in milk yield during lactation leads to a mismatch

between nutrient requirements and the animals' adaptation to the negative energy and protein balance caused by the characteristics of late pregnancy and early lactation. For these reasons, numerous metabolic diseases often occur at the beginning of lactation, causing losses in dairy farming.

In their report, J.R. Roche *et al.* (2013) noted that reduced appetite in over-conditioned cows after calving causes a negative energy balance at the beginning of lactation, which leads to increased lipolysis of adipose tissue. This, in turn, results in even greater fat mobilisation and causes more pronounced fatty liver degeneration. Intensive lactogenesis directly contributes to substantial body weight loss in the animal. Therefore, cows are forced to mobilise body reserves, particularly from adipose and muscle tissue. During early lactation, a cow may lose approximately 20 kg of muscle tissue and 8 to 57 kg of body fat. E. Bombik *et al.* (2020) demonstrated that fatty liver degeneration is one of the most important metabolic diseases in high-producing cows during the early stages of lactation. The disease usually begins about 10 days after calving. Without appropriate treatment, fatty liver degeneration may lead to other metabolic disorders, infectious diseases or reproductive problems.

J. Habel & A. Sundrum (2020) indicated that an increased plasma level of non-esterified fatty acids (NEFAs) results from adipose tissue remodelling, which leads to their uptake by the liver in proportion to their plasma concentration. A concurrent deficiency of oxaloacetate, which is largely used for gluconeogenesis, together with elevated NEFA levels, leads to the accumulation of acetylCoA in the liver. Subsequently, instead of acetyl-CoA being utilised through the complete Krebs cycle, incomplete oxidation (ketogenesis) and re-esterification occur, followed by the storage of triacylglycerols (TAGs) in the liver. In addition to the

adverse effect of accumulated TAGs on overall liver function, elevated β -hydroxybutyrate levels impair the gluconeogenic capacity of hepatocytes. Thus, lipolysis becomes excessive, and glucose balance is substantially disrupted.

However, according to P. Melendez & P. Pinedo (2024), when hepatocytes take up large amounts of NEFAs, the process of β -oxidation may become overloaded, and their excess may again be used for TAG synthesis and for the generation of very low-density lipoproteins (VLDLs) for export into the bloodstream. The export of TAGs from the liver as VLDLs is a slow process in cattle and decreases during intense fatty acid oxidation and ketogenesis, leading to TAG accumulation in the liver. S. Oikawa *et al.* (2010) noted that TAGs in the liver are not broken down, oxidised or removed, and signs of fatty hepatodystrophy therefore develop rapidly.

Accordingly, D. Đuričić & M. Sablić (2025) demonstrated that treatment of affected animals should be aimed at restoring glucose and glycogen levels in the body, normalising acid-base balance and the functions of the liver, cardiovascular system and digestive system, and restoring mineral and vitamin metabolism. V.V. Vlizlo *et al.* (2021) indicated that a shortage of sugar, a low ratio between readily available carbohydrates and digestible protein, and other feeding-related factors cause metabolic disorders in cows. A dietary sugar deficiency intensifies gluconeogenesis, the mobilisation of lipids from depots and their accumulation in the liver. By contrast, P. Mandevu *et al.* (2003) noted that preparations which reduce the mobilisation of fatty acids from adipose tissue or increase the export of lipoproteins from the liver may be used to prevent fatty liver degeneration and ketosis.

V. Horobets (2021) noted that the daily addition of protected vitamins, including choline, folic acid, riboflavin and vitamins A, D and E, to the diet during the transition period

increases dry matter intake in cows, improves their general health after calving and reproductive function, and normalises metabolism. As reported by J.M. Bollatti (2020), feeding protected choline to cows during the transition period increased milk yield and milk components, while also ensuring efficient feed utilisation during the first 105 days after calving, regardless of the animal's body condition. The author concluded that the use of protected choline reduces the nutrient requirements for maintenance in cows at the beginning of lactation or improves the uptake and transport of nutrients for the synthesis of milk components. Moreover, its effect on cow productivity is not necessarily mediated by improved markers of metabolic health or reduced TAG levels in the liver.

Studies conducted in the USA and the Netherlands have repeatedly shown that the addition of protected choline to the diet of cows promotes phospholipid synthesis and, according to M.A. Caudill (2010), substantially reduces fat accumulation in the liver. Ö. Kizil & M. Kizil (2023) indicated that magnesium deficiency in the blood plasma of cows with fatty liver degeneration, or hepatic lipidosis, during the early stages of lactation is not a direct cause of this condition, but only a contributing factor, as deficiency of this macroelement may aggravate inflammation and stress. At the same time, an adequate magnesium supply supports metabolism by helping to prevent excessive fat mobilisation, or lipolysis, which leads to fatty liver degeneration.

According to A. Pirestani & M. Aghakhani (2018), the addition of betaine to the diet of highproducing cows during the transition period has lipotropic, hepatoprotective and productivityenhancing effects. Betaine stimulates the export of TAGs from the liver by increasing the availability of methionine and S-adenosylmethionine (SAM) for the synthesis of phosphatidylcholine and apoproteins. It

also induces the expression of genes involved in fatty acid β -oxidation, has antioxidant and anti-inflammatory effects, and improves cellular resistance to heat stress.

The studies cited above confirm the substantial effect of chemically diverse substances on metabolism in high-producing cows during the period of increasing milk yield. However, the development and testing of a complex preparation for the treatment and prevention of metabolic diseases in cows during the transition period remains relevant, as does the study of its effect on the functional state of the liver, particularly the activity of cellular enzymes and selected metabolites of carbohydrate and lipid metabolism.

Materials and Methods

The studies were conducted during 2025 under the conditions of an industrial farm in eastern Ukraine, using Holstein cattle. The farm was free from infectious and invasive diseases. The cows were kept in standard tied-housing facilities. The lighting level in the building where the cows were housed was 200 lux. The floor in the cow area was covered with rubber mats. Feeding took place at a feed table positioned at the level of the sole of the cow's forelimbs. The animals were supplied with tap water through automatic drinkers.

Cows on days 50-70 of their first lactation were selected for the experiment, corresponding to the period of intensive increase in milk productivity. Two groups were formed: a control group and an experimental group, with 10 animals in each. The cows' diet consisted of the following feeds: hay, straw, maize silage, haylage, cornage, molasses and compound feed containing sunflower and soybean meal, as well as wheat, maize, chalk, salt, a premix for dairy cows and a buffer. All feed ingredients were mixed into a single total mixed ration in the proportions specified in the prescribed diet.

The dietary components were calculated and included in the diet in the amounts required for the corresponding physiological period of the cows and their needs during this period.

The cows in the control group received feed according to the standard diet. The cows in the experimental group received the same diet and the experimental complex preparation Metanorm, hereinafter referred to as the complex preparation. The preparation contains essential minerals, including magnesium, zinc, cobalt, copper, manganese, iron and molybdenum, as well as silymarin, methionine, choline chloride, L-carnitine, betaine, niacin and vitamin E, which have a positive effect on metabolism in animals. The preparation was administered at a dose of 40.7 g per animal once daily for 20 days. The clinical status of cows in both groups was assessed using generally accepted methods. During the study, the animals' habitus, the condition of the visible mucous membranes, hair coat, skin, superficial lymph nodes, and individual organs and systems were evaluated.

For the laboratory study, blood samples were collected from the cows before administration of the preparation, 10 and 20 days afterwards. For the analysis of biochemical blood parameters, samples were collected from five cows in each group into sterile disposable vacuum tubes containing silicon dioxide as a clot activator. During transport, the blood samples were stored in an insulated bag with cold packs and separated by a layer of cotton wool to slow biochemical processes in whole blood cells and, consequently, prevent changes in blood parameters.

The necessary methods, reagents and instruments were selected for laboratory studies to determine metabolic parameters in cows. Blood serum analysis included determination of lipoprotein content (total fraction), NEFAs, beta-hydroxybutyrate, vitamins A and E, glucose, total calcium and inorganic phosphorus, as well as the activity of aspartate

aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP). Biochemical parameters were determined using an automatic biochemical analyser, Biochem-200, HTI (USA), with biochemical reagents produced by HTI (High Technology Inc., USA). Vitamin levels were determined using a high-performance liquid chromatograph, LC 300, PerkinElmer (USA), with a reversed-phase C18 column. Laboratory studies were carried out at the Biosafety Centre, the Research Centre for Biosafety and Environmental Control of Agro-Industrial Resources, Dnipro State Agrarian and Economic University, Dnipro.

Statistical processing of the study results was performed using Microsoft Excel 2016. The significance of the obtained results was determined using Student's t-test. A difference between values was considered statistically significant when the coefficient (P) did not exceed 0.05, which is a generally accepted approach in scientific research.

During the experiment involving the use of the newly developed preparation to normalise metabolism in cows after the end of the transition period on a dairy farm, all bioethical requirements concerning animals were observed in accordance with Law of Ukraine No. 249 (2012) and the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (1986).

Results and Discussion

The choice of the complex preparation as a means of preventing metabolic pathologies in highproducing cows was associated with its composition, which includes a complex of essential macro- and microelements, as well as substances of different chemical nature: silymarin, protected methionine, choline chloride, L-carnitine, betaine and vitamin E. These components have a positive effect on metabolic processes in animals. The action of the

preparation is primarily aimed at preventing the most common metabolic pathologies of the transition period, namely ketosis and hepatic lipidosis, by optimising metabolism and thereby normalising biochemical blood parameters. A major advantage is the integrated approach to preventing the development of irreversible changes in cows during negative energy balance in the period of intensive lactation.

Before the complex preparation was administered, the clinical signs of metabolic disorders in cows were not pronounced. Among the existing symptoms, mild depression, reduced mobility and a pale pink conjunctival colour were observed, while the pulse rate was at the upper limit of the physiological range or slightly increased. The cows' appetite was variable and reduced; pica and weak rumen contractions were also recorded. Body temperature in these animals remained within the physiological range. In some cows, the area of hepatic dullness extended beyond the last rib. The

superficial lymph nodes accessible for clinical examination showed no visible changes. After 20 days of complex preparation and administration, cows in the experimental group consumed feed more actively; the animals rose readily and approached the feeder at each feed distribution. Signs of pica disappeared.

Determination of AST activity in blood serum is important for early diagnosis and for monitoring treatment in cows. Before administration of the complex preparation, serum AST activity in cows of both the control and experimental groups exceeded the upper limit of the physiological range (Table 1). This indicated liver cell damage caused by fatty infiltration, as V.I. Levchenko *et al.* (2002) noted that, with the development of fatty hepatosis in cows, AST activity rises above the upper limit of the physiological range already at the stage of ultramicroscopic organ changes, when the activity of other enzymes still changes only slightly.

Table 1. Blood serum enzymes in the experimental cows during the transition period, $M \pm m$, $n = 5$

Parameter	At the beginning of the experiment/before administration of the preparation		10 days after administration of the preparation		20 days after administration of the preparation		Reference range
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group	
Aspartate aminotransferase, U/L	128.33 $\pm$ 12.76	101.33 $\pm$ 4.36	134.33 $\pm$ 15.26	92.67 $\pm$ 4.01*	153.0 $\pm$ 6.27	49.33 $\pm$ 6.39* Δ	10-50
Alanine aminotransferase, U/L	29.33 $\pm$ 1.52	26.67 $\pm$ 0.76	33.67 $\pm$ 1.87	30.0 $\pm$ 1.59	34.67 $\pm$ 1.84	34.0 $\pm$ 0.37*	10-40
De Ritis ratio (AST/ALT), units	4.43 $\pm$ 0.54	3.82 $\pm$ 0.22	4.09 $\pm$ 0.65	3.13 $\pm$ 0.24	4.46 $\pm$ 0.27	1.44 $\pm$ 0.17* Δ	1.03.4
Alkaline phosphatase, U/L	128.0 $\pm$ 8.4	98.67 $\pm$ 3.27 Δ	169.0 $\pm$ 25.96	109.0 $\pm$ 4.15 Δ	138.13 $\pm$ 16.17	125.33 $\pm$ 60.79*	20150

Note: * – $P < 0.05$, significant compared with the value before administration of the preparation; $\Delta P < 0.05$, significant compared with the control group

Source: authors' development

Observation of cows in the control group and determination of serum AST activity over the 20-day experiment showed a tendency towards an increase of 19.2% compared with the

value recorded before administration of the preparation. This indicates a gradual increase in damage to the cell membranes of the liver. By contrast, administration of the complex

preparation to cows in the experimental group reduced serum AST activity by 8.5% as early as day 10 and by 2.05 times on day 20 compared with the value at the beginning of the experiment. On day 20 of complex preparation administration, serum AST activity in cows of the experimental group was significantly lower than that in cows of the control group, by more than 3 times. This indicates that the ingredients of the administered preparation contributed to the restoration of cell membranes and the liver parenchyma as a whole, and also led to normalisation of the functional state of the liver.

For cattle, the assessment of AST activity in blood serum is more informative, whereas ALT has relatively low activity in the cells of large animals. During the study, ALT activity remained within the physiological range. Following administration of the complex preparation, serum ALT activity in cows of the experimental group increased significantly by 27.4% compared with the value recorded before treatment. An increase in ALT activity within the physiological range may indicate greater intensity of metabolic processes in cows under the influence of the ingredients of the complex preparation. Consistent changes were also observed in the De Ritis ratio, which is determined as the ratio of serum AST activity to ALT activity. On day 20 of complex preparation administration, the De Ritis ratio in the blood serum of cows in the experimental group decreased significantly by 2.6 times compared with its value before administration of the preparation and by 3 times compared with its level in animals of the control group on day 20 of the experiment.

Throughout the study period, serum ALP activity in cows showed minor fluctuations both over time within each group and between the groups. However, its values remained within physiological limits. Before administration of the complex preparation, serum ALP activity

in cows of the experimental group was significantly lower, by 22.9%, than that in cows of the control group. After 10 days of the experimental period, the significant difference remained, and ALP activity in the blood serum of animals in the experimental group was 35.5% lower. However, after 20 days of the experiment, the activity of this enzyme in cows of the experimental group was remaining 9.3% lower, although no significant difference between these values was recorded. The increase in serum ALP activity in cows of the experimental group within the physiological range may indicate more intensive metabolism in the mammary gland, caused by increased milk yield. After 20 days of complex preparation and administration, cows in the experimental group, unlike animals in the control group, showed a significant increase in milk yield of 3.4 L per animal compared with the beginning of the experiment.

During the analysis of biochemical blood parameters before administration of the complex preparation, a low serum glucose concentration was found in cows of both the control and experimental groups (Table 2). This value was below the minimum physiological reference level. This may indicate a carbohydrate deficiency in the feed components of the diet during intensive lactation and confirms that the animals were in a state of negative energy balance. According to data published by the National Academies of Sciences (2021), plasma glucose concentration decreases after calving. Under physiological conditions, glycogen reserves in the liver of cows begin to be replenished and increase by day 14 after calving. This probably reflects activation of the gluconeogenic metabolic pathway of glucose formation in hepatocytes, which is important for maintaining an adequate level of lactation. If this process is impaired, the cow may develop ketosis, lipomobilisation syndrome and hepatic lipidosis.

Table 2. Biochemical parameters in the blood serum of the experimental cows during the transition period, $M \pm m$, $n = 5$

Parameter	At the beginning of the experiment/before administration of the preparation		10 days after administration of the preparation		20 days after administration of the preparation		Reference range
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group	
Glucose, mmol/L	2.23 $\pm$ 0.04	2.07 $\pm$ 0.02	2.57 $\pm$ 0.04	2.60 $\pm$ 0.04*	2.37 $\pm$ 0.06	2.60 $\pm$ 0.13*	2.54.16
Vitamin E, μ g/mL	5.46 $\pm$ 0.48	3.83 $\pm$ 0.54	6.47 $\pm$ 0.63	4.9 $\pm$ 0.61	6.39 $\pm$ 0.54	8.02 $\pm$ 0.70*	3.014.0
Vitamin A, μ g/100 mL	23.52 $\pm$ 0.85	22.26 $\pm$ 0.65	30.68 $\pm$ 0.21*	25.89 $\pm$ 2.06	26.54 $\pm$ 1.35	30.24 $\pm$ 2.82*	12.550.0
Non-esterified fatty acids, mmol/L	0.52 $\pm$ 0.03	0.54 $\pm$ 0.04	0.48 $\pm$ 0.04	0.32 $\pm$ 0.04* Δ	0.49 $\pm$ 0.04	0.25 $\pm$ 0.04* Δ	up to 0.25
Beta-hydroxybutyrate, mmol/L	1.14 $\pm$ 0.04	1.17 $\pm$ 0.04	1.07 $\pm$ 0.05	0.89 $\pm$ 0.04* Δ	1.09 $\pm$ 0.05	0.67 $\pm$ 0.05 * Δ	0.6-0.8
Lipoproteins, mg%	442.0 $\pm$ 37.59	438.67 $\pm$ 38.87	436.33 $\pm$ 39.79	655.20 $\pm$ 53.17* Δ	594.0 $\pm$ 36.72	683.0 $\pm$ 41.91*	400800
Total calcium, mmol/L	2.57 $\pm$ 0.02	2.43 $\pm$ 0.02 Δ	2.5 $\pm$ 0.04	2.5 $\pm$ 0.04	2.4 $\pm$ 0.04	2.53 $\pm$ 0.06	2.43.12
Inorganic phosphorus, mmol/L	2.03 $\pm$ 0.07	1.87 $\pm$ 0.11	1.77 $\pm$ 0.18	1.6 $\pm$ 0.04	2.27 $\pm$ 0.06	2.03 $\pm$ 0.15	1.5-2.2
Ca/P, units	1.27 $\pm$ 0.03	1.33 $\pm$ 0.08	1.53 $\pm$ 0.15	1.57 $\pm$ 0.02	1.07 $\pm$ 0.04	1.27 $\pm$ 0.11	1.2-1.6

Note: * – $P < 0.05$, significant compared with the value before administration of the preparation; $\Delta P < 0.05$, significant compared with the control group

Source: authors' development

As a result of administering the complex preparation, a significant increase in serum glucose concentration was recorded in cows of the experimental group on both day 10 and day 20, by 25.6% compared with the value at the beginning of the experiment. During this period, a tendency towards an increase in serum glucose content was also observed in animals of the control group. However, after 20 days, its content remained below the lower limit of the physiological range and was 9.7% lower than that in the blood serum of cows in the experimental group. The increase in serum glucose content in cows of the experimental group compared with the control group after 20 days of complex preparation administration may be due to the presence of cobalt in its composition. Cobalt chloride enhances the breakdown of fibre by rumen microorganisms and, according to O.O. Skyba (2005), glucose synthesis in animals

decreases under hypocobaltosis. The increase in serum glucose content in cows of the experimental group under the effect of the complex preparation contributed to the normalisation of glucose levels and prevented metabolic disorders associated with glucose deficiency. In addition, M. Ardalan *et al.* (2010) reported the effect of another ingredient of the complex preparation, protected choline. In particular, the authors assessed the effect of choline on the incidence and severity of ketosis in cows fed protected choline during the periparturient or transition period. This was accompanied by a significant increase in blood glucose content and a decrease in the levels of fatty acids and β -hydroxybutyrate. The effect of the complex preparation on selected indicators of lipid metabolism and fat-soluble vitamins in the blood serum of cows during the period of increasing lactation was studied. Before administration

of the preparation, the content of vitamin E in the blood serum of cows in the experimental group was at the lower limit of the physiological range, whereas in the blood serum of cows in the control group, this indicator was 42.6% higher, although no significant difference was recorded (Table 2).

The low content of vitamin E in the blood serum of cows in the experimental group may be a sign of fatty liver degeneration. I. Politis (2012) noted that low vitamin E content is associated with reduced hepatocyte function, for example, lower intensity of gluconeogenesis and ureagenesis, increased oxidative stress indicators, such as a lower plasma α -tocopherol concentration, and intensified inflammation. At the same time, L.M. Sordillo (2013) also reported a decrease in plasma α -tocopherol concentration during the transition period, which, in the author's view, may affect immune function. Therefore, a deficient level of vitamin E may contribute to the activation of oxidative stress, thereby provoking the development of immunosuppression.

Administration of the complex preparation to cows led to a significant increase in vitamin E content in the blood serum of cows in the experimental group after 20 days, by almost 2.1 times compared with its level in these animals before the preparation was used. In the blood serum of cows in the control group, only a tendency towards an increase in vitamin E content was found: by 18.5% on day 10 and by 17.0% on day 20 compared with this indicator at the beginning of the experiment. On day 20 of preparation administration, vitamin E content in the blood serum of cows in the experimental group was 25.5% higher than that in cows of the control group. The increase in serum vitamin E content in cows of the experimental group may indicate restoration of the antioxidant status of the experimental animals under the effect of the complex preparation, as vitamin E acts

in the body as a stabiliser of unsaturated fatty acid metabolism. This prevents the formation of peroxide and hydroperoxide compounds, provides antioxidant protection and thereby maintains the integrity of cell membranes.

The vitamin A content in the serum of cows in both groups remained within the physiological range throughout the experiment. At the same time, certain fluctuations and differences were recorded in the serum vitamin A content of cows in the control and experimental groups. In the blood serum of cows in the control group, vitamin A content increased significantly by 30.4% after 10 days of the experimental period compared with the value at the beginning. In the blood serum of cows in the experimental group, vitamin A content also increased significantly, by 35.8%, after 20 days of the experimental period, compared with the value recorded before administration of the complex preparation. Administration of the complex preparation contributed to a tendency towards a 13.9% increase in vitamin A content in the blood serum of cows in the experimental group on day 20 compared with that in cows of the control group. The increase in vitamin A content in the blood serum of cows in the experimental group may contribute to the stabilisation of the structural state of cell membranes and to a reduction in the activity of indicator enzymes. K. Schulz *et al.* (2025) noted that vitamin A plays an important role in the interaction of proteins and lipids in cell membranes, supports their function and regulates permeability, while its deficiency increases the elimination of cellular enzymes. In addition, vitamin A plays a significant role in maintaining the functional state of the liver and prevents the development of hepatic lipidoses in dairy cows, while its deficiency may intensify metabolic stress. Ensuring an adequate level of vitamin A in the blood supports liver and immune cell function, reducing the

incidence of fatty liver degeneration and related metabolic disorders.

R. Jorritsma *et al.* (2001) demonstrated that plasma NEFA levels in cows increase when animals are in a state of negative energy balance. This may occur when dry matter intake decreases during the prepartum period and almost always occurs during the first few weeks of lactation, since feed intake is low while energy requirements are high, leading to mobilisation of body reserves. Before administration of the complex preparation, serum NEFA levels in cows were high compared with reference values. Since serum NEFA levels are elevated in most cows during the perinatal period, a certain degree of fat accumulation in the liver is observed in early lactation. As shown by H. Abu Damir *et al.* (1994), low glucagon content leads to low blood glucose concentration, low insulin levels and high fatty acid mobilisation, causing lipomobilisation and fatty degeneration of the liver.

Administration of the complex preparation to cows in the experimental group led to a significant decrease in serum NEFA content: by 40.7% as early as day 10 and by 2.16 times on day 20 compared with the value at the beginning of the experiment. In the blood serum of cows in the control group, this indicator decreased by only 5.8% after 20 days of the experimental period compared with the value at the beginning of the experiment. On day 20 of complex preparation administration, the NEFA content in the blood serum of cows in the experimental group decreased by 1.96 times compared with that in cows of the control group. The reduction in NEFA content (Table 2) in the blood serum of cows in the experimental group under the effect of the complex preparation indicated positive metabolic changes in the body and a reduction in lipomobilisation syndrome. By contrast, signs of lipomobilisation syndrome remained in cows of the control group. These changes may be due to inclusion of magnesium

in the complex preparation. N.C. Ünal *et al.* (2025) found that magnesium has a moderate negative correlation with NEFAs and a moderate positive correlation with glucose. The obtained results indicated that NEFA levels increase due to negative energy balance and against the background of hypomagnesaemia. Magnesium deficiency may indirectly increase the incidence of transition-period diseases in dairy cows and weaken their metabolic adaptation. Ö. Kizil & M. Kizil (2023) noted that magnesium deficiency in the blood plasma of cows with fatty liver degeneration, or hepatic lipodosis, during the early stages of lactation is not a direct cause of this condition, but only a contributing factor, as magnesium deficiency may aggravate inflammation and stress. At the same time, an adequate magnesium supply supports metabolism by helping to prevent excessive fat mobilisation, or lipolysis, which leads to fatty liver degeneration. Magnesium is involved in numerous enzymatic reactions in the liver related to carbohydrate metabolism and protein synthesis. It also supports antioxidant defence mechanisms, protecting liver cells from peroxide damage.

The most characteristic signs of lipomobilization syndrome and fatty hepatodystrophy include weight loss, reduced milk productivity, a depressed general condition and other clinical manifestations. The 4.2 L decrease in milk yield in cows of the control group after 20 days of the experimental period, compared with the baseline value, may confirm this. I. Pishchan (2017) indicated that the mobilisation of reserve body lipids in animals inhibits feed intake, suppresses the fat-synthesising function of the udder parenchyma and may lead to ketosis. As a result, the energy efficiency of milk synthesis decreases, in contrast to the use of energy obtained directly from feed.

Excessive formation of NEFAs as a result of lipolysis in fat depots activates the production

of ketone bodies. Therefore, the beta-hydroxybutyrate content in the blood serum of cows at the beginning of the experiment was above the upper limit of the physiological range (Table 2). This indicated strain on metabolic processes associated with insufficient dietary energy and, consequently, lipomobilisation syndrome in lactating cows. Administration of the complex preparation to lactating cows led to a significant reduction in beta-hydroxybutyrate content: by 23.9% on day 10 and by 42.7% on day 20 compared with the value recorded before its use. The beta-hydroxybutyrate content in the blood serum of cows in the experimental group decreased significantly on days 10 and 20 of the experimental period, by 16.8% and 61.5%, respectively, compared with the value recorded in cows of the control group. The decrease in NEFA and beta-hydroxybutyrate content in the blood serum of cows in the experimental group may be due to the presence of cobalt, niacin and L-carnitine in the complex preparation. As demonstrated by U. Nuber *et al.* (2016), parenteral administration of a commercial mixture of butaphosphan, an organic phosphorus compound, and vitamin B₁₂ before calving or at the beginning of lactation reduced the plasma concentration of NEFAs and β -hydroxybutyrate in cows. Niacin, which is included in the complex preparation, also contributed to the reduction in these indicators. According to Y. Lin *et al.* (2025), the use of a protected form of niacin for the prevention and treatment of hepatic lipodosis in dairy cows during the transition period suppressed lipolysis, reduced the release of NEFAs from adipose tissue and decreased the level of ketone bodies. U.M. Vus *et al.* (2025) noted that the use of L-carnitine in dry-period cows has positive effects on energy metabolism, reduces the concentration of ketone bodies in the blood, improves milk productivity and reproductive function, and lowers the risk of fatty hepatosis by stimulating fatty acid oxidation

and reducing their accumulation in hepatocytes as TAGs. The main function of carnitine is to transport long-chain fatty acids (C16-C22) across the inner mitochondrial membrane for β -oxidation. Activated fatty acids in the form of acyl-CoA cannot cross the inner mitochondrial membrane independently because it is impermeable to CoA derivatives. Carnitine plays a critical role in energy metabolism by providing a substrate for β -oxidation and ATP formation. In high-producing cows during the transition period, which are in a state of negative energy balance with intensive fatty acid mobilisation, the need for carnitine increases to ensure adequate mitochondrial oxidation of these fatty acids.

The content of total lipoproteins in the blood serum of cows in the control and experimental groups remained within the physiological range throughout the study period. No difference in the content of total lipoproteins in the blood serum of cows in the control and experimental groups was observed before the beginning of the experiment. In the blood serum of cows in the control group, after 20 days of the experimental period, a tendency towards a 34.4% increase in total lipoprotein content was found compared with this indicator in cows at the beginning of the experiment. In the blood serum of cows in the experimental group, the level of total lipoproteins increased significantly by 49.4% after only 10 days of complex preparation administration and by 55.7% on day 20 compared with the value recorded before administration of the preparation. The content of the total lipoprotein fraction in the blood serum of cows in the experimental group increased significantly after 10 and 20 days of complex preparation administration, by 50.2% and 15.0%, respectively, compared with this indicator in cows of the control group. The increase in the content of the total lipoprotein fraction in the blood serum of cows in the experimental group was due to the inclusion of

lipotropic substances in the complex preparation. In this context, J.K. Drackley (2026) noted that lipotropic substances include a group of nutrients capable of preventing excessive lipid accumulation in the liver by stimulating their mobilisation and export in lipoproteins. V.V. Sakhniuk *et al.* (2017) found that lipotropic substances, including methionine, choline, betaine, L-carnitine, vitamin B₁₂ and others, exert a preventive effect against fatty hepatosis in cows by increasing synthesis and supplying methyl groups for phosphatidylcholine synthesis, the transport of long-chain fatty acids and other processes. This is important for the formation and secretion of VLDLs by stimulating the synthesis of apolipoprotein B100, the protein component of VLDLs. This process occurs through maintenance of the glutathione pool, via cysteine, a key antioxidant that protects hepatocytes from oxidative damage. According to U. Arshad *et al.* (2023), the requirement for choline in high-producing cows during the transition period increased markedly because of its secretion in milk, as part of phosphatidylcholine and sphingomyelin, and its use in the synthesis of VLDL phospholipids, the export of which from the liver intensifies under conditions of fat reserve mobilisation.

Throughout the study period, no significant fluctuations in total calcium content were found in the blood serum of cows in the control and experimental groups. Similar results were also obtained for inorganic phosphorus content, except for a slight increase of 0.07 mmol/L above the upper limit of the physiological range in the blood serum of cows in the control group on day 20 of the experiment. The calcium-to-phosphorus ratio in the blood of the experimental cows remained within the physiological range throughout the experiment. On the one hand, this indicated stabilisation of calcium/phosphorus metabolism in cows after calving and, on the other hand, showed that the

administered preparation did not affect these parameters.

Based on the study results, the complex preparation with hepatoprotective action was found to have a corrective effect on the clinical status of the body and on the metabolism of carbohydrates, lipids, vitamins and minerals, as well as on the enzymatic activity of cow blood serum during the transition period. In particular, its ability to prevent excessive fat mobilisation, or lipolysis, from fat depots and the accumulation of NEFAs and β -hydroxybutyrate in the blood plasma of cows was experimentally confirmed. These processes cause the development of fatty liver degeneration and other secondary complications. The use of this preparation is especially important during the transition period, which is the most critical stage for lactating cows and is characterised by negative energy balance.

Conclusions

Examination of cows before administration of the complex experimental preparation showed the presence of mild clinical signs of metabolic disorders, characterised by depression, reduced mobility, pale conjunctiva, variable and reduced appetite, pica, weak rumen contractions and, in some cows, areas of hepatic dullness extending beyond the last rib. Minor changes were also observed in the biochemical parameters of cow blood serum before administration of the complex preparation, in particular: low glucose content, NEFA and beta-hydroxybutyrate levels above the upper limit of the physiological range, high AST activity and an increased De Ritis ratio. Administration of the complex preparation, based on essential mineral elements, silymarin, methionine, choline chloride, L-carnitine, betaine and vitamin E, which have a positive effect on metabolic processes in cows, contributed to a reduction in clinical signs, restoration of appetite and an increase in productivity by

4.0 L per cow per day. After administration of the complex preparation to the experimental cows for 20 days, a significant increase in serum glucose concentration by 25.6% and a decrease in NEFA and beta-hydroxybutyrate levels by 2.16 times and 42.7%, respectively, were recorded. This indicated the restoration of energy metabolism and the recovery of cows in the experimental group from negative energy balance. At the same time, after 20 days of complex preparation administration, serum AST activity in cows decreased by 51.3% compared with the value at the beginning of the experiment and by more than three times compared with its activity in the blood serum of cows in the control group. Vitamin E content increased by 2.1 times compared with the value at the beginning of the experiment and by 25.5% compared with cows in the control group. This indicated

restoration of the antioxidant status in cows of the experimental group and stabilisation of the structural state of hepatocyte cell membranes. No substantial effect on calcium-phosphorus metabolism in cows was recorded after administration of the complex preparation.

A promising area for further research is to determine the effect of the complex preparation on immune status indicators and protein metabolism in cows during the transition period.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Корекція клініко-біохімічного статусу організму високопродуктивних корів транзитного періоду

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Анотація. Актуальність дослідження зумовлена зростанням випадків діагностування метаболічних хвороб у високоудійних корів під час транзитного періоду, зокрема кетозу, жирового гепатозу та їх ускладнень у вигляді цирозу печінки, репродуктивних дисфункцій з наступною ранньою вибраковкою корів. Важливу роль відіграють своєчасні заходи з профілактики метаболічних хвороб транзитного періоду, що передбачають застосування засобів коригувальної терапії для нормалізації обміну речовин й підвищення продуктивності. Тому, метою цієї роботи було дослідити вплив комплексного препарату на показники клініко-біохімічного статусу організму високопродуктивних корів під час транзитного періоду. Для проведення дослідів було сформовано дві групи: контрольну і дослідну, по 10 корів у кожній. Під час відтворення дослідів використовували загальні методи клінічного обстеження корів (огляд, пальпацію, перкусію і термометрію) та біохімічного дослідження показників сироватки крові (спектрофотометрію та хроматографію), що спрямо встановленню біологічних маркерів з оцінки змін клінічного стану та окремих ланок метаболізму в організмі корів під дією комплексного препарату. Застосування комплексного препарату на основі біологічно активних речовин призводило до підвищення в сироватці крові корів дослідної групи вмісту глюкози (на 25,6 %), сумарної фракції ліпопротеїдів (на 55,7 %), вітамінів А (на 35,9 %) та Е (в 2,1 раза) та зниження активності аспартатамінотрансферази (на 51,3 %), величини коефіцієнта де Рітиса (на 62,3 %), рівня неестерифікованих жирних кислот (у 2,16 раза) і бета-гідроксибутирату (на 42,7 %). Раннє визначення причин порушення обміну речовин та патологічних змін у печінці високопродуктивних корів у транзитний період та вчасне застосування з профілактичною метою комплексного препарату на основі біологічно активних компонентів дало можливість запобігти розвитку вторинних захворювань, зокрема жирової гепатодистрофії, зменшити економічні втрати від недоотримання молока і вибракування корів в умовах конкретного господарства

Ключові слова: печінка; гепатодистрофія; загальний клінічний стан організму; біохімічний аналіз; спектрофотометрія; високоефективна рідинна хроматографія; біологічно активні речовини



2026. Volume 17, No. 2 P. 92-110

ISSN 2663-967X;

e-ISSN 2663-9688

Journal homepage: <https://veterinaryscience.com.ua/en>

DOI: 10.31548/veterinary2.2026.92

UDC 636.044:616.31-006

Received: 09.02.2026 Revised: 04.05.2026 Accepted: 21.05.2026 Published: 28.05.2026

Oral cavity neoplasms in companion animals: Clinical features and approaches to diagnosis and treatment

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Suggested Citation:

Kulida, M., Nicpoń, J., Mazurkevych, T., Solonin, P., & Gorkava, I. (2026). Oral cavity neoplasms in companion animals: Clinical features and approaches to diagnosis and treatment. *Ukrainian Journal of Veterinary Sciences*, 17(2), 92-110. doi: 10.31548/veterinary2.2026.92.

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Abstract. The relevance of this study is determined by the high prevalence of oral cavity neoplasms in companion animals, the difficulty of their early diagnosis, and the limited possibilities for effective treatment at advanced stages of the disease. In this regard, the present scientific work is devoted to identifying the clinical and morphological characteristics of oral cavity neoplasms in dogs and cats, as well as assessing the effectiveness of contemporary approaches to their diagnosis and therapeutic management. The principal research method was clinical and diagnostic analysis, which included the synthesis of findings from clinical examinations, imaging studies, and morphological investigations. During the study, 43 clinical cases of oral cavity neoplasms in companion animals were analysed, with older cats constituting the majority of cases. It was noted that squamous cell carcinoma was diagnosed in 86% of cases and was characterised by aggressive progression and invasion of bone tissue. The study established that tumours were most frequently localised in the maxilla and mandible, the sublingual region, and the tongue (59.5% of cases). Neoplastic processes in dogs, in which not only malignant neoplasms such as squamous cell sarcoma (68.8%) but also benign tumours (16.6%) were diagnosed, were recorded in adulthood. It was substantiated that the clinical manifestations included the formation of tumour masses, ulcerative lesions, destruction of bone tissue, and impairment of oral cavity functions. It was determined that diagnostic effectiveness largely depended on the application of a comprehensive approach incorporating clinical examination, imaging techniques, and histological verification of the diagnosis. The study found that the choice of therapeutic strategy was determined by the localisation and extent of tumour spread and may include surgical intervention, targeted therapy, or palliative treatment. The materials presented in this article are of practical value to veterinary practitioners, as they contribute to improving the effectiveness of the diagnosis and treatment of oral cavity neoplasms in companion animals

Keywords: cats; dogs; veterinary oncology; bone invasion; maxilla and mandible; sublingual region; tongue

Introduction

Diseases of the oral cavity and teeth are common in animals. These include periodontal disease, early gingivitis, tooth resorption, endodontic diseases and dental trauma, chronic gingivostomatitis in cats, developmental abnormalities such as malocclusion, oral lesions and tumours. Neoplasms localised in the oral cavity of companion animals are one of the most pressing issues in modern veterinary oncology. Their prevalence in the dog and cat population, combined with the difficulty of early diagnosis, rapid progression and significant impact on the quality and duration of the animals' lives, highlights the need for in-depth study of this group of diseases.

Recent epidemiological studies have demonstrated significant variability in the morphological forms of oral cavity tumours, encompassing a wide spectrum of both benign and malignant neoplasms. P. Brilhante-Simões *et al.* (2025a) pointed to the considerable heterogeneity of histological structures and the clinical behaviour of tumour processes, which complicates the development of uniform diagnostic criteria and prognostic models. The authors emphasised that effective management of cancer patients requires the integration of clinical, morphological and imaging data into a unified diagnostic system. As established by C. Satthathum *et al.* (2023), a significant

proportion of oral neoplasms are malignant processes characterised by invasive growth and the ability to metastasise, which significantly complicates the prediction of clinical course and is accompanied by the development of halitosis in animals.

B.G. Murphy *et al.* (2025) identified two key categories of odontogenic neoplasms: tumours arising exclusively from odontogenic epithelium and tumours with features of induction. The first group comprises mainly various morphological variants of ameloblastomas, as well as other neoplasms, in particular odontogenic carcinoma and squamous cell odontogenic tumours. The second group comprises neoplasms characterised by inductive tissue interaction, including odontomas and less differentiated or structurally organised forms, such as ameloblastic fibroma and ameloblastic fibro-odontoma. In general, odontogenic tumours manifest as voluminous, expansively growing lesions localised in the region of the dental structures of the upper or lower jaw. Cases of ectopic development of such neoplasms in cats have been reported extremely rarely. Tumours of the oral cavity, according to S. Ahn & J.H. Yun (2026), were of significance in comparative oncology. In cats, squamous cell carcinoma of the oral cavity predominated and was very similar in its biological behaviour to the disease in humans. However, in dogs, a high incidence of oral melanoma was observed, a tumour that is rarely found in humans and cats.

As noted by H. Lobprise *et al.* (2025), melanoma, squamous cell carcinoma and fibrosarcoma were the most common types of malignant tumours of the oral cavity in animals. These neoplasms, according to the results obtained by R.C. Smedley *et al.* (2022), exhibited aggressive biological behaviour, manifested by rapid local invasion and a high frequency of metastatic involvement of regional lymph nodes and distant organs. According to a report by D. Giacobino *et*

al. (2025), oral melanoma is characterised by a particularly unfavourable clinical course. It is an aggressive tumour characterised by rapid growth and high local invasiveness, with a recorded metastasis rate, from the time of detection to follow-up, and following treatment, ranging from 30.3 to 74.0% in regional lymph nodes and from 14.0 to 92.0% in the lungs and other distant sites, distinguished by early systemic spread and a poor response to therapeutic interventions. In this context, as established by M.N. Mayer & S.L. Sukut (2025), staging of the lymphatic system was considered a key element of prognostic assessment, directly influencing the choice of treatment strategy. The diagnostic process for suspected oral neoplasms is based on a multidisciplinary approach combining clinical examination, cytological and histological verification, and modern medical imaging techniques.

Despite significant progress in the diagnosis and treatment of oral neoplasms in companion animals, a number of clinical and methodological aspects remain underdeveloped. In particular, there is a need to improve algorithms for the early detection of tumours, standardise diagnostic criteria, and evaluate the effectiveness of combined therapeutic approaches in real-world clinical settings. This highlights the need for further research aimed at systematising clinical experience and optimising approaches to the management of oncology patients in veterinary practice.

The aim of the study was to investigate the clinical characteristics of oral cavity neoplasms in companion animals, determine their morphological structure, and evaluate the effectiveness of modern diagnostic and treatment methods based on an analysis of clinical data.

Literature Review

Neoplastic processes of the oral cavity in companion animals are one of the most complex

and, at the same time, most extensively studied problems in modern veterinary oncology. Their significance is due to their high incidence, the considerable biological aggressiveness of most malignant forms, and the difficulties in early detection, which significantly affect the prognosis and effectiveness of treatment. S. Ahn & J.H. Yun (2026) demonstrated that this group of pathologies is characterised by considerable morphological diversity and variability in clinical course, which complicates the standardisation of diagnostic approaches and prognosis.

Epidemiological studies have shown that oncological diseases in dogs and cats account for a significant proportion of all pathologies, with a considerable number of these occurring specifically in the oral cavity. According to M. Mikiewicz *et al.* (2019), oral cavity pathologies in dogs and cats are more commonly represented by benign tumours, hyperplastic lesions and inflammatory lesions; furthermore, in dogs, gingival hyperplasia and peripheral odontogenic fibroma were diagnosed, whilst in cats, chronic lymphoplasmacytic stomatitis was diagnosed. Among malignant tumours, the most common were high-grade melanoma in dogs and squamous cell carcinoma in cats. P. Brilhante-Simões *et al.* (2025a), in a large-scale analysis of cytological cases, noted that neoplasms exhibited a wide range of histological types, requiring a comprehensive approach to diagnosis. In turn, another study by these authors, P. Brilhante-Simões *et al.* (2025b), emphasised the importance of a systematic analysis of oncological processes in the canine population to improve clinical management.

Among malignant neoplasms of the oral cavity, the most clinically significant are squamous cell carcinoma, melanoma and fibrosarcoma, which are characterised by invasive growth and high metastatic potential. These tumours are often diagnosed at late stages of development due to the absence of specific clinical

symptoms in the early stages. In particular, as stated by Y. Xia *et al.* (2024), oral melanoma is considered aggressive, exhibiting a tendency for early metastasis to regional lymph nodes and the lungs. Considerable attention in modern veterinary oncology is paid to the staging of the tumour process. M.N. Mayer & S.L. Sukut (2025) emphasised that the assessment of lymph node status is a critical prognostic factor determining further treatment strategies and the patient's overall prognosis. In turn, D. Giacobino *et al.* (2025) demonstrated that the extent of metastatic disease directly correlates with survival in animals with oral melanoma. Diagnostic approaches to oral cavity neoplasms include clinical examination, cytological and histological methods, as well as modern imaging techniques. An important component of modern diagnosis is the histopathological and cytological verification of tumours. S. Goldschmidt *et al.* (2023) found that preoperative assessment is crucial for planning the extent of surgical intervention.

Alongside surgical methods, radiotherapy is becoming increasingly important as an alternative or adjunct to surgical treatment, demonstrating efficacy in controlling locally advanced tumour processes. According to data from P. Gualtieri *et al.* (2025), modern stereotactic radiotherapy regimens have enabled the stabilisation of tumour growth and an improvement in the animals' quality of life, whilst hypofractionated radiotherapy has provided effective local control of tumour growth. A positive effect of preventive irradiation of lymph nodes on the control of oral melanoma has been established. Furthermore, targeted therapeutic strategies aimed at blocking intracellular signalling cascades responsible for tumour cell proliferation are being actively developed. W.P. Katt *et al.* (2025) reported on the promise of MAPK/ERK pathway inhibitors as a potential avenue for personalised cancer therapy. The authors

demonstrated the efficacy of the MEK inhibitor (trametinib) in inhibiting the growth of squamous cell carcinoma cells of the oral cavity.

Molecular studies provide a deeper understanding of tumour pathogenesis. G. Mucignat *et al.* (2024) found that transcriptomic analysis of oral melanoma enables the identification of genetic signatures associated with prognosis and response to treatment. This has opened up possibilities for personalised treatment. Comparative oncology also plays an important role in understanding the mechanisms of tumour development. W.S. Kim *et al.* (2021) demonstrated the similarity of biological processes in animals and humans, making veterinary models important for translational research. A. Lo Giudice *et al.* (2024) described the establishment of melanoma cell cultures, which enabled *in vitro* studies of tumour growth and the testing of new therapeutic agents. This represents an important step in the development of experimental oncology.

Thus, oncological diseases in dogs are characterised by significant variability in clinical manifestations and histological variants, which complicates the standardisation of diagnostic approaches. The authors emphasised the importance of systematising data from cytological and histological studies to improve the epidemiological understanding of tumour processes, including those of oral origin. Summarising the literature, it can be stated that modern veterinary oncology has made significant progress in the diagnosis and treatment of oral neoplasms. At the same time, issues regarding early diagnosis, the standardisation of therapeutic protocols and the optimisation of combined treatment methods remain unresolved, highlighting the need for further research in this field; there is also a continuing need for the further integration of clinical, morphological and molecular data to develop more effective diagnostic and therapeutic algorithms.

Materials and Methods

The study was conducted throughout 2025 at the Department of Veterinary Surgery named after Academician I.O. Povazhenko, National University of Life and Environmental Sciences of Ukraine and the “Vetlife” veterinary clinic in Kyiv. The study was retrospective in nature and was based on the analysis of medical records and the results of clinical, instrumental, cytological and histological examinations of the animals. The inclusion criterion for companion animals (dogs and cats) in the sample was the presence of a neoplasm (tumour) in the oral cavity. A total of 43 clinical cases were analysed: cats ($n = 37$), aged 3 to 17 years, and dogs ($n = 6$), aged 8 to 10 years. In clinical practice, a comprehensive diagnostic approach was employed, comprising clinical examination, imaging techniques and morphological verification. Histological examination confirmed the tumour type and assessed the degree of differentiation. All 43 clinical cases underwent the same diagnostic work-up, specifically cytological and histological examination, whilst radiography and computed tomography (CT) were used selectively depending on the clinical situation. An analysis of the available results of the relevant examinations was conducted.

The clinical examination included: a general examination of the animals, an assessment of the condition of the oral cavity tissues, and palpation of neoplasms and regional lymph nodes. To refine the diagnosis, instrumental diagnostic methods were employed, including radiographic examination using a high-frequency portable X-ray system, the Cubex 50 (JPI Healthcare, South Korea), and CT using the Philips MX 8000 IDT (Netherlands). Morphological verification of the diagnosis was carried out using cytological and histological methods. Fine-needle aspiration biopsy was performed to obtain cytological sample. A fine needle (22G) was inserted into the neoplasm and negative pressure

(aspiration) was created using a syringe to collect cells. The collected cellular material was applied to a microscope slide, a smear was prepared, and after drying, it was examined under an “Olympus CX 43” microscope (Labdepo, Japan).

For histological examination, biopsies were used, which were obtained by performing incisional or excisional biopsies of samples for microscopic examination. The samples were placed in histological cassettes and fixed for 48 hours in a 10% aqueous neutral formalin solution, after which they were rinsed for 24 hours in tap water. To remove water from the samples, dehydration was carried out using ethyl alcohol of increasing concentration (60°, 70°, 96°, 100°) for one to three hours. The material was then placed in a mixture of alcohol and chloroform, followed by immersion in pure chloroform, after which the material was placed in a chloroform-paraffin mixture (at 37°C) and in paraffin (at 55-56°C). A casting station and stainless steel moulds were used to produce paraffin blocks. Histological sections up to 5-10 µm thick were prepared from the paraffin blocks using an MPS-2 sliding microtome (MedTech-Price, Ukraine). Subsequently, the histological sections were stained with haematoxylin and eosin according to Mallory and impregnated according to Kelemen, in accordance with standard procedures. The preparations were examined using an “Olympus CX 43” binocular microscope (Labdepo, Japan) and an eyepiece micrometer.

The results obtained during the studies were recorded in the form of protocols, and statistical data analysis was performed on a personal computer using StatSoft Statistica 13.1 (2016) software. Microphotography of individual histological sections of affected oral cavity tissues was performed using a microscope fitted with a “Primo Star” digital camera (Carl Zeiss, Germany) and connected to a personal computer.

Diagnostic and therapeutic interventions were performed according to clinical indications. Informed consent was obtained from the animal owners for the performance of diagnostic procedures and the use of anonymised clinical data for scientific purposes. Scientific research involving animals complied with the requirements of the European Convention for the Protection of Vertebrate Animals Used for Research and Other Scientific Purposes (1986) and Law of Ukraine No. 3447-IV (2006). All necessary procedures on animals were carried out in accordance with the ARRIVE guidelines, without contravening the principles of Directive No. 2010/63/EU (2010) on the protection of animals used for scientific purposes.

Results and Discussion

An analysis of clinical cases recorded at the “Vetlife” veterinary clinic (Kyiv) confirmed a high prevalence of malignant tumours of the oral cavity in companion animals, particularly in cats. The ages of the animals studied varied. Cats were examined at ages ranging from 3 to 17 years, and dogs from 8 to 10 years. However, the majority of patients, over 80% of cases, belonged to the older age group (>10 years). In the sample, the average age of cats was 12.8 years, and of dogs 9.3 years. In older animals (over 12 years) in the sample, 90% of inoperable forms were recorded – a trend also confirmed by studies conducted by D. Khayatan *et al.* (2023). By species, cats predominated in the sample: 37 cases out of 43 (≈86%), whilst dogs accounted for 6 cases (≈14%). In terms of sex, a slight predominance of tumours in females was noted, as the quantitative distribution of animals by sex showed that of the 43 animals in the sample, 23 were females and 20 were males. Analysis of 43 clinical cases of oral cavity neoplasms in companion animals revealed a predominance of malignant neoplasms of

epithelial origin. In particular, squamous cell carcinoma was diagnosed in 37 animals (86%), indicating the predominance of this tumour

type in the study sample. The clinical picture of tumour lesions of the soft tissues of the oral cavity in cats is presented in Figure 1.



Figure 1. Results of clinical examinations of cats with soft-tissue tumours in the oral cavity

Note: a – neoplasm in the necrotic stage in the left masseter region; b – neoplasm in the hard palate region, anaemia of the oral mucosa; c – neoplasm of the hard palate; d – neoplasm in the dorsal surface of the tongue; e – neoplasm of the lateral edge of the tongue; f – lesion of the soft palate tissues; g – lesion of the upper lip; h – tumourous lesion of the upper jaw gums; i – lesion of the sublingual region of the oral cavity

Source: authors' photo

Clinically, the neoplasms in cats manifested as tumour masses of varying sizes. Tissue indurations, nodular formations and erosions were localised on the mucous membrane, on the tongue and in the sublingual region. Ulcerative lesions of the palate, lips and cheeks were accompanied by bleeding, difficulty eating and halitosis. Moreover, a sharp, unpleasant odour

emanating from the mouth was caused by necrosis (decay) of tumour tissues and the development of a bacterial infection. The main clinical signs were: the presence of tumour masses in the region of the jaws, tongue or cheeks, ulcerative lesions, loosening of teeth, tissue oedema, as well as signs of invasion into bone tissue (bone lysis, deformation of anatomical structures) (Fig. 2).



Figure 2. Results of clinical examination

of cats with tumours affecting the bone tissue in the oral cavity

Note: a – neoplasm in the necrotic stage in the mandible with bone lysis, anterior view; b – neoplasm in the necrotic stage in the mandible with bone lysis, inferior view; c – local deformation of the jawbone (firm, immobile swelling) in a cat with a neoplasm in the lower jaw region (external view); d – tissue breakdown of a malignant tumour in a cat with a neoplasm in the lower jaw region (view from the oral cavity)

Source: authors' photo

In a significant number of cases, tumour invasion into bone tissue was observed, manifesting as bone lysis and deformation of the jaws. Such changes are typical of the aggressive course of squamous cell carcinoma. In a number of cases, metastatic involvement was recorded, particularly of regional lymph nodes and distant

tissues, indicating progression of the tumour process. Clinically, the neoplasms manifested as: tumour masses of varying sizes, ulcerative lesions, bleeding, impaired food intake, deformation of anatomical structures and halitosis. In dogs, the clinical manifestations of neoplasms localised in the oral cavity are shown in Figure 3.

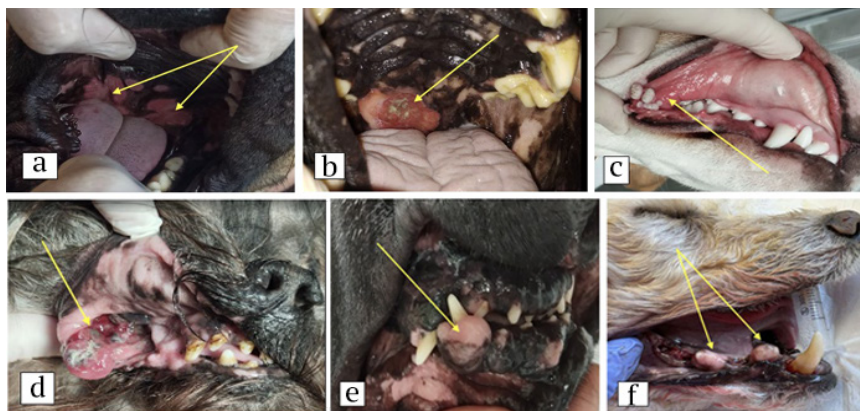


Figure 3. Results of clinical examinations of dogs with tumorous lesions of the oral cavity tissues

Note: a – diffuse tumorous lesion of tissues in the hard palate region; b – localised neoplasm in the hard palate region; c – neoplasm in the corner of the mouth appearing as white patches on the buccal mucosa; d – tissue proliferation with an erosive area on the buccal mucosa; e – localised, soft, asymmetrical enlargement of the gums; f – firm, nodular, pink growths

Source: authors' photo

Oral neoplasms in dogs are located on the mucous membrane of the palate, cheeks and gums. They appear as diffuse or localised, nodular, firm lesions of varying colours (white, pink, red or brown). As a result of tissue necrosis and tumour breakdown, halitosis and hypersalivation with traces of blood are present. During feeding, dysphagia and bleeding from the oral cavity were observed, particularly during chewing. In cases of gingival involvement, tooth mobility and tooth loss were noted. During clinical examination of the animals, the following localisation of tumours in the oral cavity was identified (Fig. 4).

It was found that in cats, lesions of the oral cavity tissues were localised in the lower or

upper jaw in over 50% of cases, whilst in some cats, multifocal lesions were observed, specifically involving the jaw, gums and tongue simultaneously. In dogs, lesions of the upper jaw and oral mucosa were most frequently observed (66.8%). The results of the examination revealed that in cats, the lower and upper jaws were the main sites of tumour localisation (37.8% and 21.7%, respectively), whereas in dogs, lesions of the cheek mucosa, soft palate and gums were predominant (16.6% each).

To establish an accurate diagnosis, histological examination (65% of cases), cytological puncture (23%) and imaging methods (X-ray, CT – 12%) were used. Bone invasion was detected in 68% of cases in cats. Metastases (in

lymph nodes or lungs) were diagnosed in 15% of animals at the stage of tumour necrosis; in 43% of animals (16 cats and 3 dogs), the tumours were found to be inoperable. An accurate diagnosis was established for the animals under study based on the results of histological examination of the affected tissues, in which epithelial neoplasia with squamous differentiation of tumour cells was observed. There were strands of squamous-differentiated atypical keratinocytes associated with the epidermis,

exhibiting nuclear polymorphism, hyperchromasia and mitoses of tumour cells (1 mitosis per 10 large fields of view under the microscope). The tumour cells had irregular borders, visible intercellular contacts, abundant, strongly eosinophilic cytoplasm, round or oval nuclei with fine-grained chromatin and 1-3 prominent nucleoli. At the same time, anisokaryosis was moderate, with keratin pearls and keratinisation of individual cells present, accompanied by associated mixed-cell inflammation (Fig. 5).

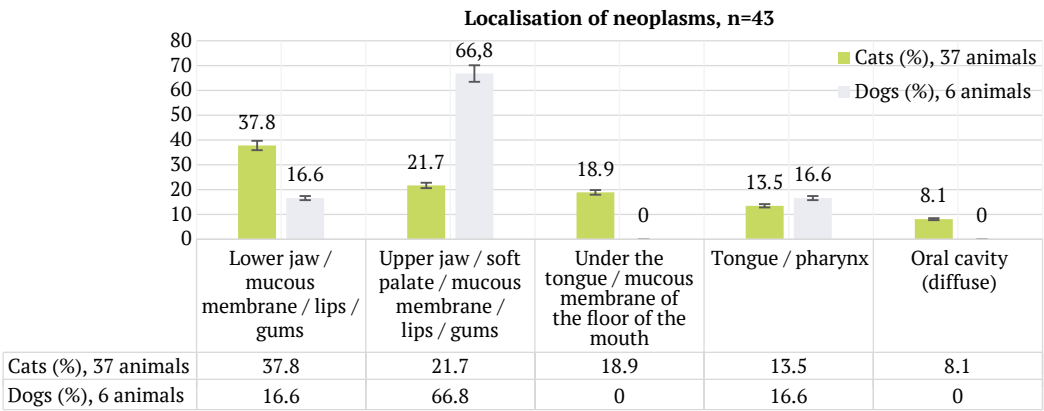


Figure 4. Localisation of neoplasms in the study animals

Source: authors' own work

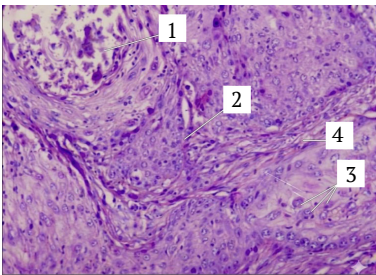


Figure 5. Histological appearance of a G2 squamous cell carcinoma of oral cavity tissue in a cat
Note: 1 – concentric accumulation of eosinophilic keratin in the centre of the epithelial layer, indicating keratinisation of the tumour; 2 – massive proliferation of tumour cells infiltrating the stroma; 3 – enlarged hyperchromic nuclei of tumour cells with irregular contours; 4 – connective tissue with signs of inflammatory infiltration surrounding the tumour complexes
Source: authors' photo

Oral carcinomas in cats are characterised by a marked tendency towards invasive growth, particularly invasion into the underlying bone tissue of the lower or upper jaw. This may be

accompanied by bone destruction, tooth loss, pain, difficulty eating and pathological fractures. The poor prognosis for squamous cell carcinoma of the oral cavity in cats is associated with the difficulty of achieving clear resection margins, high local invasiveness, a tendency to recur, and the potential for metastasis to regional lymph nodes and the lungs. A more detailed histological picture of squamous cell carcinoma of the oral cavity in cats, in particular the formation of keratin pearls and the desmoplastic reaction of the stroma, is shown in Figure 6.

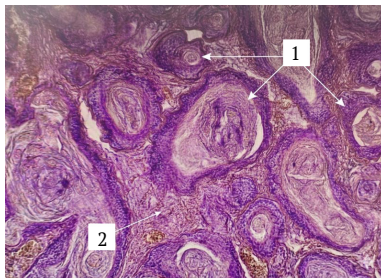


Figure 6. Histological appearance of squamous cell carcinoma of the oral cavity in a cat (H&E stain, $\times 400$ magnification)

Note: 1 – mature keratin pearls with characteristic keratin layering; 2 – area of marked desmoplastic stromal reaction with fibroblast proliferation around invasive epithelial nests

Source: authors' photo

As shown in Figure 6, the histological specimen contains tumour nests composed of dense concentric masses of keratin, known as “keratin pearls”. Surrounding the “keratin pearls” are pleomorphic cells exhibiting features of anisocytosis and anisokaryosis. The nuclei are large and vesicular, with coarse chromatin and visible nucleoli. An intense reactive proliferation of fibrous connective tissue is present around the tumour complexes.

Based on the results of morphological examination and clinical assessment, it was

established that in most cases squamous cell carcinoma was characterised by an aggressive course with marked invasion into bone tissue. In one of the examined samples of squamous cell carcinoma, characteristic histological features were identified – the formation of keratin pearls and moderate anisokaryosis, confirming the differentiated type of carcinoma. Similar morphological characteristics are described in the works of K. Feigin & C. Bell (2024), who pointed to significant histological variability of tumours, which influences their biological behaviour and prognosis. The results obtained are consistent with those of S. Goldschmidt *et al.* (2025) in that clinically, the neoplasms manifested as invasion into bone tissue (lysis, deformation of the jaws), the formation of ulcerated surfaces, pain and impaired food intake, and in some cases, metastasis, which underscored the aggressiveness of local tumour growth in the oral cavity.

A comparison of the morphological structure of the neoplasms in the studied animals revealed that in cats, invasive variants with deep invasion into bone tissue and the formation of “keratin pearls” predominated, whereas in dogs, superficial, erosive-ulcerative forms were more frequently observed, confirming the observations of K. Feigin & C. Bell (2024) regarding the dependence of the histological type of tumour on the species of animal. In this study, bone invasion was observed in 68% of cats, which is consistent with the data obtained by D. Giacobino *et al.* (2025), who reported 65% of cases of infiltration in dogs with squamous cell carcinoma. This correlation demonstrates the universality of the pathomorphological mechanisms of invasion, regardless of species and geographical region.

The combined use of methods (histopathology with radiography, or cytology with CT) improved accuracy, particularly in determining invasion into bone tissue. The distribution of diagnosed tumour types is shown in Figure 7.

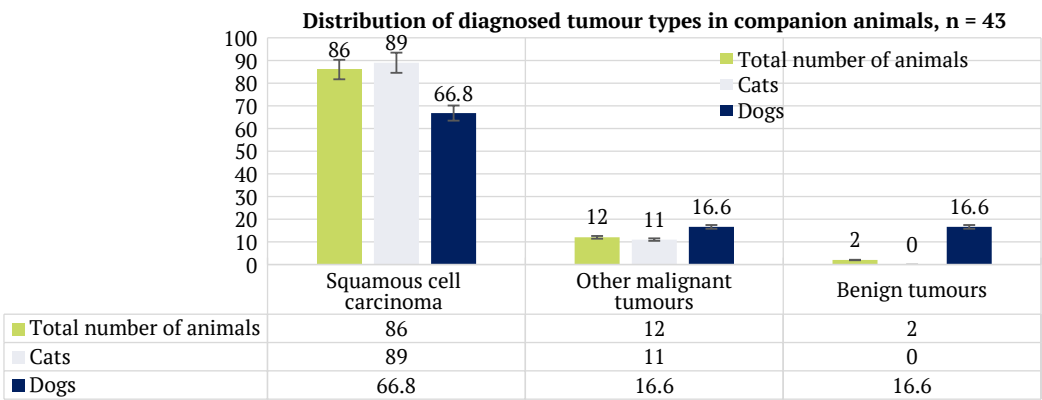


Figure 7. Distribution of diagnosed tumour types in companion animals
Source: authors' own work

Figure 7 shows a clear imbalance in the distribution of tumour types: malignant forms together account for the vast majority of cases, indicating the seriousness of oral cancer in companion animals as a whole. What is most significant is not so much the dominance of squamous cell carcinoma in itself, but rather the fundamental difference between species within the category of benign neoplasms: in cats, this is zero. This means that the detection of any oral neoplasm in a cat effectively indicates, with a very high probability, a malignant process – which has direct practical implications for the clinical decision to proceed with urgent intervention without waiting for further confirmation. In dogs, however, the picture is more varied: benign and other malignant forms together account for a third of cases, which justifies the need for a more detailed differential diagnosis before selecting a treatment strategy.

According to the results obtained, it was established that squamous cell carcinoma is the predominant type of neoplasia, the development of which was recorded in 86% of all cases, which is consistent with the data of P. Brilhante Simões *et al.* (2025a), who noted a significant frequency of epithelial malignant

neoplasms detected during the examination of 12,671 dogs. In the present sample, this figure is even higher, which can be explained by the characteristics of the animal population and the selection of severe clinical cases. The predominance of cats in the sample (86%) may indicate a species-specific predisposition to the development of this type of tumour. It was found that the majority of animals belonged to the older age group, which is consistent with the general patterns of oncological processes.

The use of imaging methods, in particular radiography and CT, allowed the extent of bone structure involvement to be determined, which is critically important for treatment planning, as also discussed in the work by M. de Almeida *et al.* (2025). S. Goldschmidt *et al.* (2023) also noted the high diagnostic value of preoperative screening for assessing the extent of the tumour process. The cytological and histological methods used in the study demonstrated high diagnostic accuracy (over 90%). A similar accuracy of morphological methods was described by K. Feigin & C. Bell (2024), who analysed cases of ameloblastoma in dogs and emphasised that cytological assessment is effective when an experienced morphologist is available. At

the same time, M. De Almeida *et al.* (2025) emphasised the importance of CT in visualising local tumour invasion. In this study, it was CT that allowed an additional 5 cases to be classified as invasive, which had previously been considered superficial. Regarding the clinical course, stage III cancer was diagnosed in the majority of cats (45%), regardless of the type of treatment. Such a high proportion of advanced cases is consistent with the observations of S. Goldschmidt *et al.* (2023), who found that in over 60% of small animals, oral tumours were detected at late stages of development.

In this study, the radiographic sign of bone lysis was the most indicative criterion of inoperability, which fully coincides with the prognostic criteria proposed by P. Brilhante Simões *et al.* (2025b). Furthermore, S. Sabatini *et al.* (2026) demonstrated that molecular markers, such as SOX-10, can be used to identify metastatic cells in lymph nodes. S. Lee *et al.* (2021) established that CT is one of the most informative tools for assessing the extent of tumour invasion and allows for a detailed assessment of the anatomical boundaries of the lesion, the extent of invasion, and the involvement of the skull's bony structures. High-resolution imaging allows for a more precise

determination of the lesion boundaries, which is critical for planning surgical intervention. The use of high-resolution CT protocols provides a three-dimensional reconstruction of the pathological process, which significantly improves the accuracy of clinical staging. M. de Almeida *et al.* (2025) noted that the use of whole-body CT in veterinary oncology significantly improves the detection of primary tumours, substantially increasing diagnostic sensitivity, and allows for the visualisation of hidden metastases that may remain undetected during standard examination. This has a significant impact on the choice of therapeutic strategy. In addition to traditional diagnostic methods, as noted by G. Mucignat *et al.* (2024), molecular biological and immunohistochemical approaches are being actively introduced into modern veterinary oncology, enabling a more in-depth assessment of the biological nature of the tumour process. The integration of morphological and molecular markers has enabled the development of more accurate prognostic models and personalised treatment approaches. Analysis of clinical cases has shown that the choice of therapeutic strategy depends on the tumour's location, the degree of invasion, and the animal's general condition (Fig. 8).

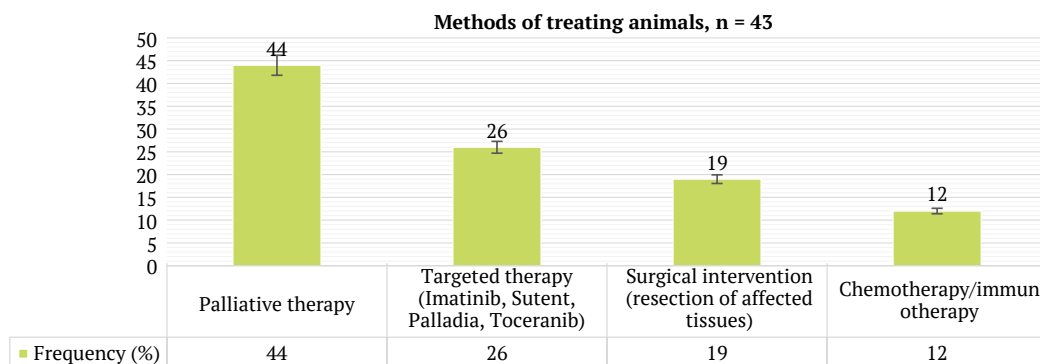


Figure 8. Methods of treating animals

Note: figures are presented as percentages (%)

Source: authors' own work

Figure 8 reveals a significant imbalance between the approaches used, which has important clinical implications. Most notably, palliative care predominates (44%) – that is, almost half of the animals received treatment aimed not at eliminating the tumour, but merely at alleviating their condition. This indirectly suggests that a significant proportion of cases were already at a stage where radical intervention was impossible or inadvisable at the time of referral. Thus, the diagram indirectly reflects the problem of late detection – not as a statistic, but as a clinical consequence. At the same time, targeted therapy (26%) and surgical intervention (19%) together account for 45% – that is, almost as much as palliative care. However, these two approaches differ fundamentally in their objectives: surgery

involves the physical removal of affected tissue, whereas targeted therapy acts systemically. The fact that targeted therapy was used more frequently than surgery may indicate the prevalence of cases with bone invasion or anatomically complex localisation, where resection is technically limited. Chemotherapy/immunotherapy (1.2%) is used in virtually isolated cases, reflecting its adjunctive rather than primary role in treatment protocols for oral tumours in companion animals.

In one clinical case involving a cat with squamous cell carcinoma of the hard palate and tongue, combined treatment was recommended (Fig. 9a-c), comprising surgical intervention combined with targeted therapy using tyrosine kinase inhibitors. Such approaches are consistent with research.

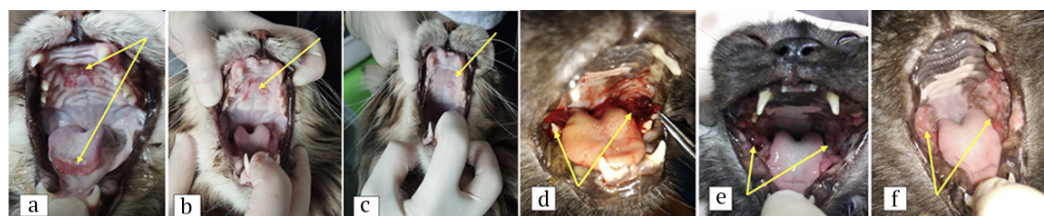


Figure 9. Treatment outcomes for cats diagnosed with squamous cell carcinoma of the oral cavity

Note: a-c – a clinical case of squamous cell carcinoma of the hard palate and tongue in a cat: a – tumour involvement of tissues in the hard palate and tongue region prior to treatment; b – tissue condition on day 16 of treatment; c – condition of the tissues on day 30 of treatment; d-f – clinical case of a neoplasm in the sublingual region and on the gums in a cat: d – neoplasm in the sublingual region and on the gums; e – treatment results on day 16; f – treatment results on day 30

Source: authors' photo

In cases involving tumours in difficult locations (Fig. 9 d-f), particularly in a cat with sublingual carcinoma, the scope for radical surgical treatment was limited. In such situations, palliative care was provided with the aim of improving the animal's quality of life. The use of multi-kinase inhibitors and antibacterial drugs allowed the inflammatory process to be controlled and tumour progression to be partially

halted. Recent research by H. He *et al.* (2024) has also confirmed the promise of radiotherapy and the latest treatment methods, including immunotherapy and targeted approaches. However, treatment issues remain complex. In the sample cited, only 19% of animals underwent surgery, whilst 44% received palliative care and 26% received targeted therapy with tyrosine kinase inhibitors (imatinib, Sutent,

Palladia, toceranib). The treatment applied was in line with the global trend of shifting from aggressive surgical interventions to combined regimens of systemic treatment. Compared with the findings of K. Feigin & C. Bell (2024), who reported remission in only 15% of patients following resection without systemic therapy, the inclusion of targeted drugs in the treatment regimen increased early stabilisation of the disease to 33%.

Some studies have noted a significant prolongation of survival when receptor inhibitors are combined with non-steroidal anti-inflammatory drugs (Piroxicam, Meloxicam), which is consistent with the clinical observations of R. Gualtieri *et al.* (2025) regarding the synergy of antitumour and anti-inflammatory effects. This provides grounds for considering combination therapy as a promising direction in veterinary oncology. The treatment strategy for oral cavity neoplasms is complex and is determined by the histological type of tumour, the stage of the disease, and the patient's general condition. Surgical removal remains the primary method, the effectiveness of which depends directly on adherence to adequate surgical margins. S. Goldschmidt *et al.* (2025) emphasised that inadequate surgical margins significantly increased the risk of local recurrence, particularly in aggressive odontogenic and epithelial neoplasms, and that the precision of surgical removal directly influences the long-term prognosis.

A comparative analysis of the present animal study with the data of P. Brilhante Simões *et al.* (2025a) revealed that the frequency of metastasis (approximately 15%) is somewhat lower than in large-scale samples (20-25%). This can be explained by the predominance of locally invasive forms without distant lesions, as well as the short duration of clinical observation. In cats, metastases were recorded mainly in the submandibular and retropharyngeal lymph

nodes. The degree of tumour differentiation also influenced the prognosis. Less differentiated forms without keratinous structures were characterised by faster growth; in such animals, the median survival did not exceed 5 months, whereas for G1-G2 tumours with marked keratinisation, the median prognosis was up to 12 months. Similar patterns were identified by K. Feigin & C. Bell (2024) in cases of low-grade ameloblastomas, where differentiation correlated directly with clinical outcome.

The use of imaging techniques – contrast-enhanced CT – proved highly effective in detecting heterogeneity in neoplasms, and the results fully corroborated the findings of M. De Almeida *et al.* (2025) regarding the advantages of CT over radiography in the diagnosis of small head and neck neoplasms in animals. The study results showed that in 12% of cases, the true extent of local invasion was determined solely through CT. In a broader context, the results obtained expand the understanding of the pathogenesis and treatment options for epithelial carcinomas in animals. P. Brilhante Simões *et al.* (2025b) indicated that scientific attention should be directed towards the systematic classification and generalisation of histological variants in relation to survival prognosis. The results obtained confirmed the practical importance of this approach, as it was precisely the morphological verification of the degree of differentiation (G1-G2) that allowed the prognosis to be refined in more than half of the patients. This indicates the universality of the pharmacological response across species, even with different dosing regimens.

Based on the results obtained, it is possible to compare the clinical and morphological characteristics of oral cavity tumours in cats and dogs with current international trends, and to confirm the conclusion reached by S. Ahn & J.H. Yun (2026) that the generalisation of malignant tumour models in animals contributes

to a deeper understanding of the similarities in oncogenesis between species. In this sense, the study of squamous cell carcinomas in cats and dogs has not only veterinary but also comparative medical significance, as it models the behaviour of similar tumours in humans.

Thus, the study results are consistent with most contemporary international research and confirm the relevance of a comprehensive approach to the diagnosis and treatment of malignant neoplasms of the oral cavity in small animals. The approach used for the diagnosis and treatment of tumours has demonstrated the importance of morphological verification, anatomical localisation, the age factor, and the use of targeted drugs as key components in predicting the survival of animals with squamous cell carcinomas. The results obtained are generally consistent with studies demonstrating the predominance of squamous cell carcinoma in cats, aggressive local growth, and limited possibilities for radical treatment in advanced stages. At the same time, a distinctive feature of this study is its focus on clinical practice within the context of local veterinary medicine, which allows for an assessment of the realistic possibilities for diagnosis and treatment. The results obtained have made it possible to confirm that oral cavity tumours in small companion animals are one of the most pressing issues in clinical veterinary oncology.

Conclusions

The study analysed 43 clinical cases and examined pathological processes in companion animals, establishing that neoplasms of the oral cavity in dogs and cats were characterised by a high prevalence of malignant forms, with squamous cell carcinoma being the most common (in 86% of the animals studied). In the study sample, the majority of animals belonged to the older age group: the vast majority of patients belonged to the geriatric group (over 10 years

old). At the same time, there was a significant numerical predominance of cats among the affected animals (86% of the total sample). The course of squamous cell carcinoma was characterised by a high degree of aggressiveness. The main complicating factor was tumour invasion into bone tissue (in 68% of the cats examined, tumour growth into the jaw was recorded), which was accompanied by bone destruction and significantly complicated treatment and worsened the prognosis of the disease. Metastasis to the lymph nodes or lungs was detected in 15% of animals at the stage of tumour disintegration. Due to the advanced stage of the disease, the tumours were inoperable in 43% of cases (16 cats and 3 dogs). The main clinical manifestations of the pathological process were the formation of tumour masses, the presence of ulcerative lesions of soft tissues, halitosis, bone destruction and impaired oral cavity function. These features significantly worsened the prognosis and complicated further therapeutic measures. It has been demonstrated that a comprehensive approach is essential for accurate diagnosis, combining the collection of medical history, a general clinical examination of the animals with a thorough examination of the patients' oral cavity, imaging techniques, and histopathological studies, all of which are necessary for accurate diagnosis and the determination of treatment strategies. It has been shown that the choice of treatment strategy depends on the tumour's location and the extent of its spread. In cases of localised neoplasms, surgical treatment was effective, whereas in cases of advanced disease, palliative or targeted therapy was used. Prospects for further research relate to the study of the efficacy of the latest treatment methods, in particular targeted and immunotherapy.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

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Новоутворення ротової порожнини у тварин-компаньйонів: клінічні особливості та підходи до діагностики і лікування

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Анотація. Актуальність дослідження зумовлена високою поширеністю новоутворень ротової порожнини у тварин-компаньйонів, складністю їх ранньої діагностики та обмеженими можливостями ефективного лікування на пізніх стадіях захворювання. У зв'язку з цим, представлений науковий матеріал присвячений визначенню клінічних і морфологічних особливостей новоутворень ротової порожнини у собак і котів, а також встановленню ефективності сучасних підходів у їх діагностиці та лікувальній тактиці. Провідним методом дослідження слугував клініко-діагностичний аналіз, що включав узагальнення результатів клінічного обстеження, візуалізаційних та морфологічних досліджень. У ході дослідження проаналізовано 43 клінічні випадки новоутворень ротової порожнини у тварин-компаньйонів, серед яких переважали коти старшої вікової групи. Зазначено, що у 86 % випадків діагностовано плоскоклітинний рак, який характеризувався агресивним перебігом та інвазією у кісткову тканину. Встановлено, що найчастіше (у 59,5 % випадків) пухлини локалізувалися у верхній та нижній щелепі, під'язиковій ділянці та язика. Пухлинні процеси у собак, серед яких діагностовано не лише злоякісні новоутворення,

такі як плоскоклітинна сарком (68,8 %), а й доброякісні (16,6 %), реєстрували у дорослому віці. Обґрунтовано, що клінічні прояви включали утворення пухлинних мас, виразкові ураження, деструкцію кісткової тканини та порушення функцій ротової порожнини. З'ясовано, що ефективність діагностики значною мірою залежала від застосування комплексного підходу, який включав клінічне обстеження, методи візуалізації та гістологічну верифікацію діагнозу. Встановлено, що вибір лікувальної тактики визначався локалізацією та ступенем поширення пухлинного процесу і може включати хірургічне втручання, таргетну або паліативну терапію. Матеріали статті становлять практичну цінність для лікарів ветеринарної медицини, оскільки сприяють підвищенню ефективності діагностики та лікування новоутворень ротової порожнини у тварин-компаньйонів

Ключові слова: коти; собаки; ветеринарна онкологія; інвазія кістки; верхня та нижня щелепи; під'язикова ділянка; язик

UKRAINIAN JOURNAL OF VETERINARY SCIENCES

Scientific journal

Vol. 17, No. 2. 2026

Founded in 2010. Published four times per year

The original layout of the publication is made in the Department of Scientific
and Technical Information of National University of Life
and Environmental Sciences of Ukraine

Managing editor:

N. Shevchenko

Signed for print of May 21, 2026.

Format 70*100/16

Conventional printed pages 9.1

Circulation 100 copies

Publisher's address:

National University of Life and Environmental Sciences of Ukraine

03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Tel.: (044) 527-82-42

E-mail: vs@veterinaryscience.com.ua

<https://veterinaryscience.com.ua/en>

УКРАЇНСЬКИЙ ЧАСОПИС ВЕТЕРИНАРНИХ НАУК

Науковий журнал

Том 17, № 2. 2026

Заснований у 2010 р. Виходить чотири рази на рік

Оригінал-макет видання виготовлено
у відділі науково-технічної інформації
Національного університету біоресурсів і природокористування України

Відповідальний редактор:

Н. Шевченко

Підписано до друку 21 травня 2026 р.

Формат 70*100/16

Умов. друк. арк. 9,1

Наклад 100 прим.

Адреса видавництва:

Національний університет біоресурсів і природокористування України

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