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## Results of iodine-based treatment application in carp aquaculture within closed water systems

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**Abstract.** The study aimed to monitor the prevalence of ectoparasites and bacterial infestations in carp and to determine effective dosages of a new iodine-based treatment for disease prevention. The research found that carp were affected by ectoparasites *G. kobayashii* at 43.32%, *L. cyprinacea* at 46.67%, and *P. lusiana* at 31.71% in fish farming facilities within the Sumy Region. Treatment with the iodine-based product resulted in a reduction of infestation levels to 0.2%, including a decrease in the incidence of

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gyrodactylosis by 89.92-97.35%, lernaecosis by 79.13-95.91%, and philometroidosis by 81.30-91.16% compared to monitoring results. In investigations of bacterial infestations, it was found that the contamination of carp was higher for *E. coli* at the PC "Shmatukha" by 8.0%, *Aeromonas hydrophila* by 47.97%, and *Aeromonas salmonicida* by 31.39%. Additionally, *Pseudomonas anguilliseptica* was detected at 19.48%, *Streptococcus iniae* at 13.27%, and *Micrococcus spp.* at 38.14% at LLC "Ryasnyanske". The presence of *Staphylococcus aureus* was recorded at 21.37%, and *Listeria monocytogenes* at 11.43% at LLC "Bdzhola"; these figures were lower than those observed in other farms. Following treatment with the iodine-based agent, contamination of fish by *E. coli* decreased by 98.96% at the PC "Shmatukha", 99.2% at LLC "Bdzhola", and 84.32% at LLC "Ryasnyanske". Contamination of carp by *A. hydrophila* decreased by 94.51% at the PC "Shmatukha", 80.28% at LLC "Bdzhola", and 99.15% at LLC "Ryasnyanske". The presence of *A. salmonicida* was reduced by 97.23% at the PC "Shmatukha", 94.00% at LLC "Bdzhola", and 79.06% at LLC "Ryasnyanske". Contamination by *S. aureus* decreased by 92.15% at the PC "Shmatukha", 98.74% at LLC "Bdzhola", and 93.89% at LLC "Ryasnyanske". The levels of *S. iniae* decreased by 80.90% at the PC "Shmatukha", 99.63% at LLC "Bdzhola", and 83.30% at LLC "Ryasnyanske". Contamination by *L. monocytogenes* was reduced by 96.25% at the PC "Shmatukha", 96.08% at LLC "Bdzhola", and 98.13% at LLC "Ryasnyanske". Furthermore, *Micrococcus spp.* levels decreased by 93.74% at the PC "Shmatukha", 96.37% at LLC "Bdzhola", and 92.26% at LLC "Ryasnyanske", in comparison to the monitoring results. The practical value of this study lies in controlling the spread of ectoparasites and developing preventive measures to eliminate ectoparasites and bacterial infestations in carp prior to their release into water bodies

**Keywords:** fish ectoparasites; intensity of invasion; bacterial microflora; control; prevention

## INTRODUCTION

The prevention of infectious diseases in commercial fish is of great importance to both producers and consumers. The development of effective and safe measures to prevent the spread of infectious agents in aquaculture is a pressing issue for scientists and farmers.

In the cultivation of commercial fish, systematic diagnostic monitoring and timely disease prevention are crucial (Kochmann *et al.*, 2023). Research by N. Peter *et al.* (2023) has shown that parasites can affect internal organs and systems, and alter fish behaviour. The prevalence of parasitic infestations in fish increases with chemical pollution of water bodies (Pravdová *et al.*, 2023). Studies by N. Umasuthan *et al.* (2020) have demonstrated that ectoparasite infestations reduce immunity and contribute to the development of bacterial and viral infestations in fish. Parasitic diseases in fish lead to significant economic losses in both wild and farmed environments. Research by G. Rigos *et al.* (2024) has shown that the lack of rotation of antiparasitic drugs in aquaculture has led to the emergence of parasite resistance. A review of antiparasitic treatments has highlighted the need for greater control and regulation of their usage.

Formalin is often used as an effective treatment for ectoparasites and fungi in fish (Othmen *et al.*, 2024). However, research by E.R. Fetherman *et al.* (2023) has shown that formalin can lead to the death of fish fry and eggs, depending on the concentration. Additionally, increasing the concentration of the disinfectant and its continuous use can lead to the development of resistance in microorganisms. Consequently, the formation of resistant bacterial strains reduces the effectiveness of the disinfectant, making its use impractical. Research by S.I. Islam *et al.* (2024) has shown that

bacterial diseases are a significant problem, affecting both wild and farmed fish species. Common pathogens include streptococci, staphylococci, *E. coli*, *Listeria*, and *Pseudomonas aeruginosa*. A thorough investigation into fish bacterial pathogens, their prevalence, and the development of control and prevention methods is necessary. Therefore, controlling the spread of bacterial infestations among wild fish populations and in aquaculture is a priority. Studies by K. Buchmann (2022) have shown that parasites adapt well to changes in their environment and to antiparasitic agents. Scientists therefore propose combining various methods for parasite control, such as chemical, mechanical, and biological. However, specific agents and protocols for antiparasitic treatment of fish have not yet been proposed. Research by S. Zhou *et al.* (2021) has demonstrated the antiparasitic activity of dioscin, an active compound in *D. collettii* var. *Hypoglauca*, against *G. kobayashii*. However, studies have shown that 0.6 mg/L of dioscin does not completely eliminate the parasite but only temporarily removes it from the host. Therefore, the development and improvement of measures to control fish ectoparasites are still ongoing.

Due to the harmful effects of chemical disinfectants on the environment and fish, researchers B.Y. Harmansa *et al.* (2023) proposed investigating the antiparasitic effects of essential oils from *Mentha piperita*, *Citrus limon* and *Melaleuca alternifolia*. The results of their studies showed that *Melaleuca alternifolia* oil was the most effective, but all three plant essential oils had a weak antiparasitic effect. Researchers Q. Ma *et al.* (2024) note that chemical compounds such as formalin, hydrogen peroxide, and mebendazole are widely used to kill fish ectoparasites. However, the frequent

use of these agents leads to increased parasite resistance and water pollution.

Fish are often contaminated with both ectoparasites and bacterial microorganisms simultaneously. Therefore, there is a need for an environmentally safe yet effective disinfectant capable of simultaneously eliminating parasites and microorganisms from the fish's surface. For treating parasitic keratitis in humans, researchers N. Szentmáry *et al.* (2020) suggested the use of povidone-iodine, which has been effective against this rare and hard-to-treat condition. A promising area of research is the exploration of a broader spectrum of antiparasitic activity of povidone-iodine. The compound has shown activity against adenoviruses, mumps, measles, and influenza, as well as enveloped and non-enveloped viruses. Studies by R. Barreto *et al.* (2020) demonstrated povidone-iodine's high antibacterial activity and its ability to disrupt bacterial biofilms when treating acute and chronic wounds in patients. There is a need to assess its effectiveness in eliminating opportunistic and pathogenic microflora on the surface of fish before stocking ponds. An evaluation of the toxic effects of Betadine (a 10% povidone-iodine solution) on goldfish fry was conducted, and researchers Y.A. Mohamadi *et al.* (2022) found that Betadine has a short half-life in aquatic environments and is non-toxic to fish. Therefore, it can be used for disinfecting closed water systems.

This study aimed to determine the correlation between ectoparasite infestation and bacterial infestations in fish and to investigate the efficacy of an iodine-based agent (active ingredient povidone-iodine) as an antiparasitic and antibacterial treatment.

## MATERIALS AND METHODS

**Monitoring of fish damage by ectoparasites and bacterial microflora.** A study on ectoparasite and bacterial infestations in fish was conducted in fish farms in the Sumy Region, Ukraine: Private Company "Shmatukha" (Solidarne village), Limited Liability Company "Bdzhol" (Kononenkovo village), and Limited Liability Company "Ryasnianske" (Ryasnianske village) during the spring-autumn period of 2023. Fish were kept in closed warm-water ponds of up to 10 hectares. These farms follow an intensive commercial fish farming system. The main commercial species was the common carp (*Cyprinus carpio*). Fish were fed balanced compound feed. Ponds were systematically fertilised with organic and mineral fertilisers and subjected to melioration. However, due to military activities, fish farming and melioration measures were not carried out at LLC "Ryasnianske", leading to a deterioration of the pond's sanitary condition. During a control catch of 100 individuals in each farm, the presence of parasites and bacterial flora was determined. The total number of fish examined across all farms was 300.

**Conducting a production study on fish treatment for the prevention of ectoparasites** (*Gyrodactylus kobayashii*, *Lernaea cyprinacea* and *Philometroides lusiana*) and bacterioses. One-year-old carp infested with ectoparasites and contaminated with bacterial microflora were placed in 100 dm<sup>3</sup> containers for treatment with Combiiod at concentrations of 0.05%, 0.1%, and 0.2%. The fish were exposed to the treatment solution for 3 hours at a temperature of +14°C. The study was conducted between April and May 2024. Three experimental groups were established (Table 1).

**Table 1.** Study design

Experiment	Number of fish per group	Concentration of agent
1E	100	0.05 %
2E	100	0.1 %
3E	100	0.2 %

**Source:** developed by the authors

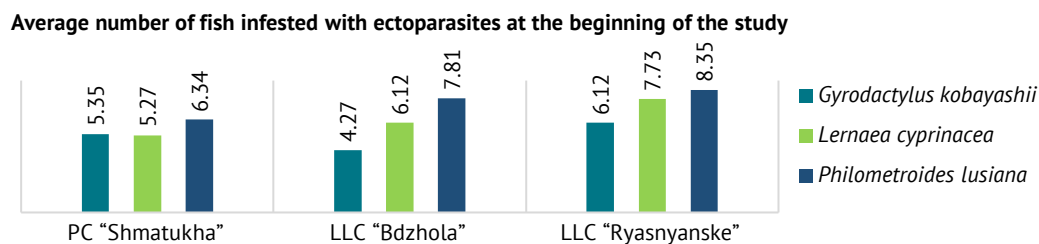
Microorganism swabs and cultivation were carried out at 37°C with a 24-hour exposure period. The experimental iodine-based agent (povidone-iodine 200 mg and sodium selenite 1.2 mg) was provided by the manufacturing company "Brovapharma". The study aimed to conduct a practical trial of fish treatment before their transfer to the pond.

**Statistical analysis.** The obtained data were processed using Microsoft Excel 2010, alongside statistical analysis employing the Fisher-Student method, accounting for statistical errors and a significance level greater than 95% ( $p < 0.05$ ). The research conducted at the fish farms adhered to the standards of DSTU

EN ISO/IEC 17025:2019 (2019) and complied with bioethics rules and the humane treatment of vertebrate animals, as per 2010/63/EU (Hartung, 2010), the European Convention (1986), and the Law of Ukraine No. 249 (2012).

## RESULTS

**Results of monitoring fish damage by ectoparasites.** At the beginning of the study, the degree of ectoparasite infestation in fish was determined in the ponds of PC "Shmatukha" (Solidarne village), LLC "Bdzhol" (Kononenkovo village), and LLC "Ryasnianske" (Ryasnianske village) during the autumn-spring period (Fig. 1).



**Figure 1.** Monitoring of ectoparasite pathogens in fish at farms in the Sumy Region

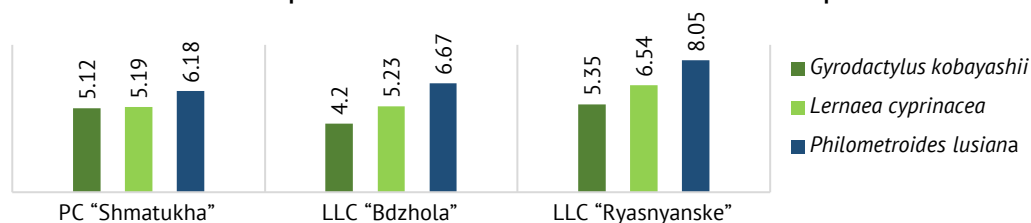
Source: developed by the authors

Infestation of carp by ectoparasites was notably higher at LLC "Ryasnianske", with *Gyrodactylus kobayashii* at 43.32%, *Lernaea cyprinacea* at 46.67%, and *Philometroides lusiana* at 31.71%, compared to the lowest rates recorded in other farms. The study revealed breaches in sanitary conditions at LLC "Ryasnianske". Disinfection of the pond is a labour-intensive and costly process. A large quantity of disinfectant is required, and it is difficult to accurately calculate the concentration of the active substance in the water or whether it will be sufficient to eliminate the parasites. A more effective and sustainable method for maintaining water quality is regular water exchange and mechanical cleaning, which reduces the risk of parasite and microorganism accumulation in the water. Additionally, to prevent the transmission of fish parasites to workers,

personal hygiene must be maintained. Additionally, treatment of infested fish is necessary to prevent the spread and reinfestation of fish in the main pond where cultivation occurs.

**Conducting a production study on the treatment of fish against ectoparasites.** The next stage of the study involved treating the fish with a 0.05% solution of treatment before stocking the ponds (Fig. 2). It was found that the level of infestation by gill flukes decreased after treatment by 4.29% at PC "Shmatukha", 1.63% at LLC "Bdzhola", and 12.58% at LLC "Ryasnianske", compared to the initial results. *Gyrodactylus spp.* are flatworms that infest bony fish, feeding on mucus and epithelial cells. Damage to the epidermis promotes the development of secondary infestations, increasing the risk of mass fish mortality.

**Average number of fish infested with ectoparasites after treatment with a 0.05% solution of the product**



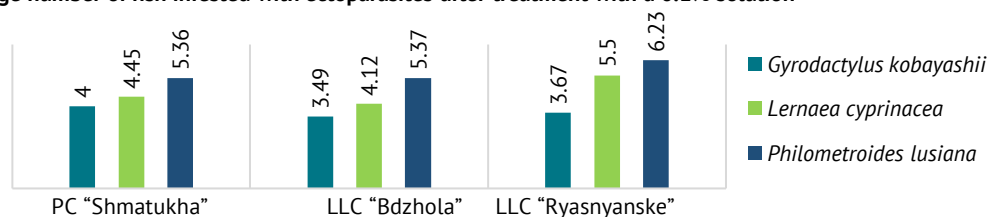
**Figure 2.** Extensiveness of ectoparasite infestation in fish after treatment with a 0.05% iodine-based solution

Source: developed by the authors

The level of fish infestation by lernaeciosis following treatment with Combiiod decreased by 1.51% at PC "Shmatukha", 14.54% at LLC "Bdzhola", and 15.39% at LLC "Ryasnianske". The number of fish with philometroidosis decreased by 2.52% at PC "Shmatukha", 14.59% at LLC "Bdzhola", and 3.59% at

LLC "Ryasnianske" compared to the results before treatment. Treatment of fish with a 0.05% solution of the agent showed low efficacy. Therefore, in subsequent experiments, the concentration of the iodine-based agent was increased to 0.1% to eliminate ectoparasites on fish (Fig. 3).

**Average number of fish infested with ectoparasites after treatment with a 0.1% solution**



**Figure 3.** Extensiveness of ectoparasite infestation in fish after treatment with a 0.1% iodine-based solution

Source: developed by the authors

Following treatment with a 0.1% solution, the efficacy against gyrodactylosis was 25.23% at PC "Shmatukha", 42.97% at LLC "Bdzhola", and 40.03% at LLC "Ryasnianske" compared to the beginning of the experiment. The parasites *Gyrodactylus kobayashii* exhibit a direct life cycle and a short generation time, allowing them to rapidly infest a significant number of fish. The infestation of fish by the parasite *Lernaea cyprinacea* decreased by 15.55% at PC "Shmatukha", 32.67% at LLC "Bdzhola", and 28.84% at LLC "Ryasnianske". The parasite *Lernaea cyprinacea* is highly invasive and infects freshwater fish in large numbers. After treatment with the iodine-based

agent the number of fish affected by philometroidosis decreased by 15.45% at PC "Shmatukha", 31.24% at LLC "Bdzhola", and 25.38% at LLC "Ryasnianske" compared to the beginning of the experiment. Philometroidosis in carp is caused by the nematode *Philometroides lusiana* from the family *Philimetridae*. The disease is severe and involves the liver, kidneys, and swim bladder. Against a background of pronounced general intoxication, the fish initially lose weight, which gradually leads to emaciation and death. To achieve maximum efficacy in eliminating ectoparasites, the concentration of the agent was increased to 0.2% (Fig. 4).

Average number of fish infested with ectoparasites after treatment with a 0.2% solution

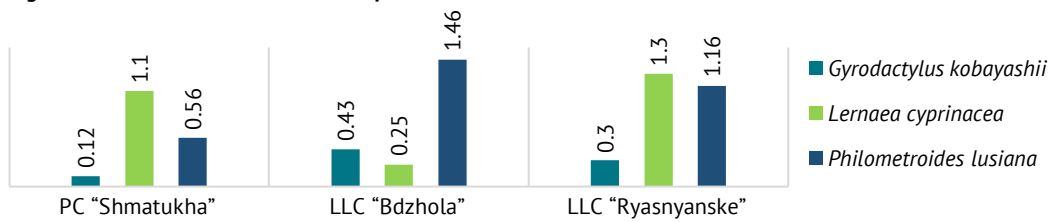


Figure 4. Extensiveness of ectoparasite infestation in fish after treatment with a 0.1% iodine-based solution

Source: developed by the authors

Treatment with a 0.2% iodine-based solution significantly reduced gyrodactylosis at PC "Shmatukha" by 97.35%, at LLC "Bdzhola" by 89.92%, and at LLC "Ryasnianske" by 95.09%, compared to the initial data. Lernaeosis was reduced by 79.13% at PC "Shmatukha", 95.91% at LLC "Bdzhola", and 83.18% at LLC "Ryasnianske". The percentage of fish with philometroidosis decreased by 91.16% at PC "Shmatukha", 81.30% at LLC "Bdzhola", and 86.11% at LLC "Ryasnianske" compared to the beginning of the study.

**Results of monitoring fish damage by ectoparasites and bacterial microflora.** The degree of fish infestation by parasites, in turn, contributes to the development of bacterial infestations and the death of a significant number of fish. Therefore, parallel monitoring of fish infestation by opportunistic bacterial microflora was carried out in fish farms in the Sumy Region (Fig. 5).

Most fish zoonoses are caused by bacteria. The prevalence of bacterial infestations in carp is constantly changing and needs to be monitored to detect infestation in both wild populations and aquaculture. The results of the study show the degree of bacterial infestation, which, against a background of ectoparasite infestation, poses a threat to both fish and human health. Contamination of carp with *Escherichia coli* was higher at PC "Shmatukha" by 8.0% compared to the lowest value. At LLC "Ryasnianske", fish infestation with *Aeromonas hydrophila* was higher by 47.97%, *Aeromonas salmonicida* by 31.39%, *Pseudomonas anguilliseptica* by 19.48%, *Streptococcus iniae* by 13.27%, and *Micrococcus spp.* by 38.14% compared to the lowest value in other farms. At LLC "Bdzhola", contamination of fish with *Staphylococcus aureus* was higher by 21.37% and *Listeria monocytogenes* by 11.43%.

Infestation of fish by bacterial microflora

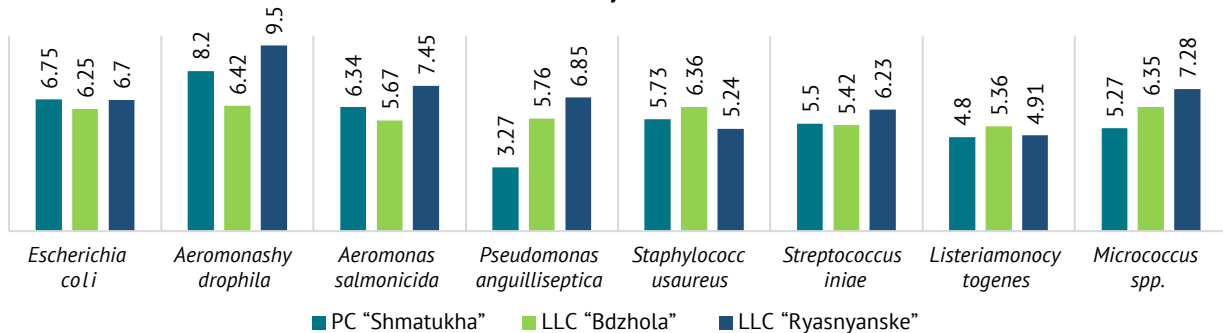


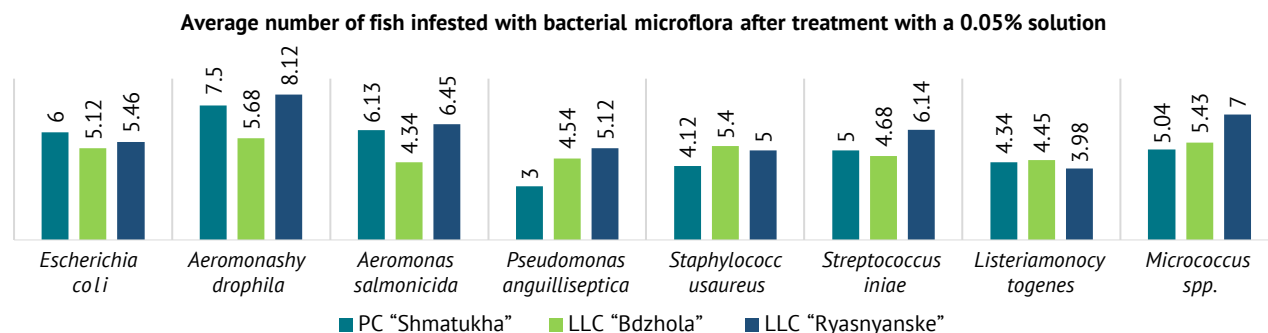
Figure 5. Monitoring of fish infestation by opportunistic bacterial microflora in farms of the Sumy Region

Source: developed by the authors

### Conducting a production study on fish processing to prevent bacterial microflora.

Fish infested with ectoparasites have a weakened immune system, making them more susceptible to bacterial infestations. To reduce the risk of infectious diseases in fish, the level of bacterial contamination was determined after treatment with a 0.05% solution (Fig. 6). Bacterial infestations in fish cultured in open water bodies can lead to significant economic losses due to disease and mortality. Therefore, finding effective solutions for the prevention and control of major bacterial diseases in fish is

crucial. Studies have shown that after treatment with a 0.05% iodine-based solution, the number of fish infested with *Escherichia coli* decreased by 11.11% at PC "Shmatukha", 18.08% at LLC "Bdzhola", and 18.50% at LLC "Ryasnianske" compared to the initial data. While *Escherichia coli* is not a specific pathogen of fish bacterial infestations, it is a zoonosis that can cause human disease. Therefore, determining the contamination of fish with *E. coli* is important for product safety and also indicates the sanitary condition of the water bodies where the fish is kept.



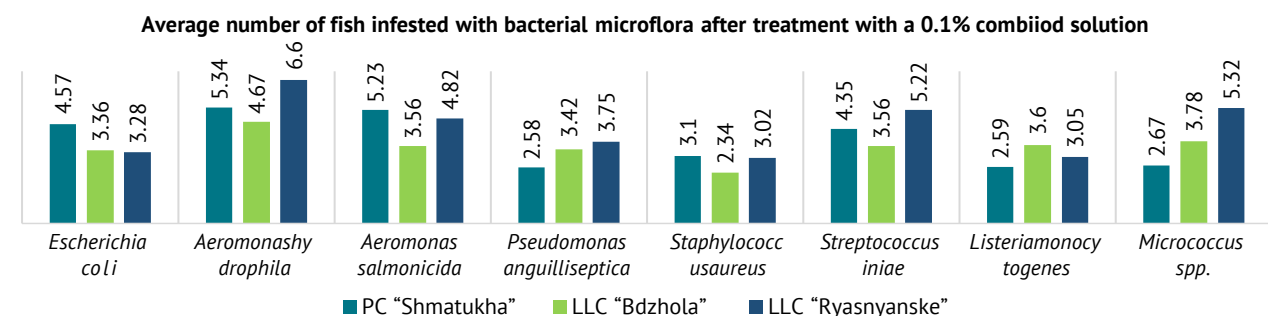
**Figure 6.** Infestation of fish with opportunistic microflora after treatment with 0.05 % iodine-based solution  
Source: developed by the authors

Aeromonosis in fish is a common cause of fish mortality due to damage to internal organs, especially the hematopoietic system. Infestations with *Aeromonas hydrophila* decreased by 8.53% at PC "Shmatukha", 11.52% at LLC "Bdzhola", and 14.52% at LLC "Ryasnianske". The percentage of fish infested with *Aeromonas salmonicida* was lower by 3.31% at PC "Shmatukha", 23.45% at LLC "Bdzhola", and 13.42% at LLC "Ryasnianske". *Pseudomonas anguilliseptica* is a conditionally pathogenic microorganism that affects various fish species. *Pseudomonas* manifests as haemorrhages, damage to internal organs, and mortality. Infestations with *Pseudomonas anguilliseptica* decreased by 8.53% at PC "Shmatukha", 21.18% at LLC "Bdzhola", and 25.26% at LLC "Ryasnianske" after treatment with a 0.05% solution, compared to monitoring data.

A decrease in staphylococcal infestation was observed at PC "Shmatukha" by 28.09%, at LLC "Bdzhola" by 17.61%, and at LLC "Ryasnianske" by 4.58%. *Staphylococcus aureus* is a conditionally pathogenic

microorganism and is an indicator of the sanitary condition of water bodies where fish are farmed. Reducing the number of staphylococci on the fish surface is important for ensuring food safety. *S. iniae* is a major causative agent of streptococcosis in wild and farmed fish worldwide. The level of *Streptococcus iniae* decreased after treatment with the agent by 9.09% at PC "Shmatukha", 13.65% at LLC "Bdzhola", and 1.44% at LLC "Ryasnianske", compared to the initial results.

*Listeria monocytogenes*, a frequent pathogen in fish, can cause enterotoxemia in humans. After treatment, the incidence of this pathogen decreased by 9.77% at PC "Shmatukha", 16.97% at LLC "Bdzhola", and 17.25% at LLC "Ryasnianske". The content of *Micrococcus spp.* on the fish surface decreased by 4.36% at PC "Shmatukha", 14.48% at LLC "Bdzhola", and 3.84% at LLC "Ryasnianske", compared to the previous monitoring. The results of fish treatment with a 0.05% iodine-based solution suggest the possibility of increasing the concentration of the agent (Fig. 7).



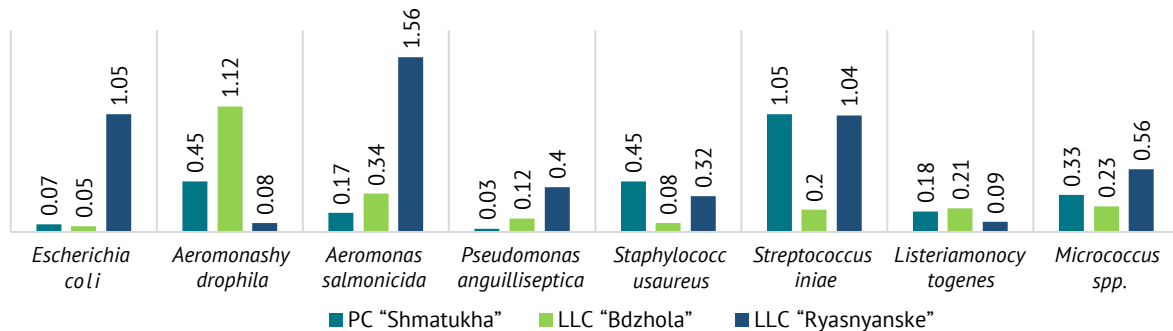
**Figure 7.** Infestation of fish with opportunistic microflora after treatment with 0.1% solution of iodine-containing solution  
Source: developed by the authors

The percentage of fish infested with *Escherichia coli* decreased by 32.29% at PC "Shmatukha", 46.24% at LLC "Bdzhola", and 51.04% at LLC "Ryasnianske" after treatment. The contamination of fish with *A. hydrophila* decreased by 34.87% at PC "Shmatukha", 50.84% at LLC "Bdzhola", and 30.52% at LLC "Ryasnianske". Fish during cultivation undergo significant stress, which reduces immunity and resistance to bacterial infestations. *Aeromonas salmonicida* causes furunculosis and severe septicaemia, leading to fish mortality. Infestations with *A. salmonicida* decreased by 17.50% at PC "Shmatukha", 37.21% at LLC "Bdzhola", and 35.30% at LLC "Ryasnianske" compared to the monitoring results.

The number of *Pseudomonas* on the fish surface decreased by 28.10% at PC "Shmatukha", 40.62% at LLC "Bdzhola", and 45.25% at LLC "Ryasnianske". The

contamination of fish with the sanitary indicator microorganism *S. aureus* decreased by 45.89% at PC "Shmatukha", 63.20% at LLC "Bdzhola", and 42.36% at LLC "Ryasnianske" compared to the initial data. The content of streptococci decreased after treatment by 20.90% at PC "Shmatukha", 34.31% at LLC "Bdzhola", and 16.21% at LLC "Ryasnianske". Infestations with *Listeria* decreased by 46.15% at PC "Shmatukha", 32.84% at LLC "Bdzhola", and 36.59% at LLC "Ryasnianske" compared to the monitoring results. The level of *Micrococcus spp.* decreased after treatment with the agent by 46.15% at PC "Shmatukha", 32.84% at LLC "Bdzhola", and 36.59% at LLC "Ryasnianske". To achieve maximum effectiveness in eliminating microorganisms, the concentration of the agent was increased to 0.2% (Fig. 8).

Average number of fish infested with bacterial microflora after treatment with a 0.2% combiiod solution



**Figure 8.** Infestation of fish with opportunistic microflora after treatment with 0.2 % iodine-containing solution  
Source: developed by the authors

As a result of the treatment, the content of *Escherichia coli* in carp decreased by 98.96% at PC "Shmatukha", 99.2% at LLC "Bdzhola", and 84.32% at LLC "Ryasnianske", compared to the beginning of the experiment. Infestations with *A. hydrophila* decreased by 94.51% at PC "Shmatukha", 80.28% at LLC "Bdzhola", and 99.15% at LLC "Ryasnianske" after treatment. The contamination of carp with *A. salmonicida* decreased by 97.23% at PC "Shmatukha", 94.00% at LLC "Bdzhola", and 79.06% at LLC "Ryasnianske" after treatment with a 0.2% agent, compared to the monitoring results. Opportunistic infestations that can affect humans include *Pseudomonas spp.*, *Micrococcus spp.*, *E. coli*, *S. aureus* and *Streptococcus spp.* The level of contamination of fish with *P. anguilliseptica* decreased by 99.08% at PC "Shmatukha", 97.91% at LLC "Bdzhola", and 99.41% at LLC "Ryasnianske".

Infestations with *S. aureus* in carp decreased by 92.15% at PC "Shmatukha", 98.74% at LLC "Bdzhola", and 93.89% at LLC "Ryasnianske" after treatment with the iodine-based agent compared to the initial data. The level of *Streptococcus iniae* decreased by 80.90% at PC "Shmatukha", 99.63% at LLC "Bdzhola", and 83.30% at LLC "Ryasnianske". The number of *L. monocytogenes*

decreased by 96.25% at PC "Shmatukha", 96.08% at LLC "Bdzhola", and 98.13% at LLC "Ryasnianske" compared to the monitoring results. Infestations with *Micrococcus spp.* in carp decreased by 93.74% at PC "Shmatukha", 96.37% at LLC "Bdzhola", and 92.26% after treatment with the agent. As a result of the conducted test, the destruction of ectoparasites and bacterial microflora on fish (carp) using the Combiiod agent at different concentrations before stocking in the pond, it was established that treatment with a 0.2% solution had the most pronounced effect.

## DISCUSSION

Carp is one of the most widely consumed fish species globally and is frequently contaminated with parasites. Many of these parasites can pose a serious threat to human health. Researchers S. Shamsi (2019) and N. Dyshliuk *et al.* (2023) have found that fish parasites often remain unidentified and lead to zoonotic diseases. Protocols and standards for testing food products for pathogens vary across countries (Williams *et al.*, 2020) and even within developed countries (Franceschini *et al.*, 2023). Scientists W. Saijuntha *et al.* (2021) have determined that the increasing demand for raw and

undercooked fish as a human food product, as well as climate change, contributes to the rise of zoonoses.

Infestations of fish with the ectoparasite *Gyrodactylus* cause a sharp decline in freshwater fish production. Researchers E.D. Renner and I.C. Duggan (2024) confirmed in their studies that the prevalence of gyrodactylosis is influenced by season and temperature. As a result of the monitoring of fish infestations with ectoparasites in fish farms, the pathogens *Gyrodactylus kobayashii*, *Lernaea cyprinacea* and *Philometroides lusiana* were identified. Of the three experimental farms, the highest percentage of infestations was recorded at LLC "Ryasnianske". The obtained result is associated with the sanitary condition of the pond. Due to the hostilities in the area, it was not cleaned for a long time. The bottom of the water body has a significant layer of silt and clay. The increased amount of soil particles in the water and low transparency prevent sunlight from destroying microorganisms and parasite larvae in the water at a significant depth. To prevent the introduction of infested individuals into the water bodies, the fish were pre-treated with an agent containing active iodine in different concentrations.

After treating carp with a 0.05% solution of the agent, the infestation of fish with gyrodactylosis (12.58%) and lernaeciosis (15.39%) decreased significantly at LLC "Ryasnianske" compared to other farms. However, the destruction of the parasite *Philometroides lusiana* (14.59%) on the fish surface was most observed at LLC "Bdzhola". Treatment of fish with a 0.05% iodine-based solution demonstrated low efficacy in terms of extent. It was established that the infestation of carp with gyrodactylosis decreased by 4.29% at PC "Shmatukha", 1.63% at LLC "Bdzhola", and 12.58% at LLC "Ryasnianske" compared to the initial results. *Gyrodactylus spp.* are flatworms that infect bony fish, feeding on mucus and epithelial cells. Damage to the epidermis promotes the development of secondary infestations, which increases the risk of death of a large number of fish. Studies by S. Zhou et al. (2022) in vivo and in vitro confirm that the antiparasitic efficacy of palm oil against *G. kobayashii* depends on the time of application and dose.

Increasing the concentration of the agent to 0.1% for treating fish against ectoparasites showed a decrease in the maximum number of parasites *G. kobayashii* and *L. cyprinacea* at LLC "Bdzhola" by 42.97% and 32.67%, respectively, compared to other fish farms. Studies on the infestation of carp with the parasite *Lernaea cyprinacea* are of great importance. Scientists H. Rahmati-Holasoo et al. (2023) studied this problem and found that it is necessary to consider the direct and indirect impact of various environmental factors on the occurrence and spread of the disease. The infestation of carp with *Philometroides lusiana* decreased significantly in the fish farm LLC "Ryasnianske" by 25.38%. In the article of F. Moravec et al. (2019), representatives of the

species *Philometridae* were studied, which represent a group of dracunculoid nematodes parasitising fish. Researchers believe that this species is so widespread on most continents that it needs to be studied in detail to increase the possibilities of developing preventive measures.

Increasing the concentration of the solution to 0.2% enabled the achievement of maximum extensity effectiveness. The destruction of gyrodactylosis in farms on the fish surface was 89.92-97.35%; lernaeciosis – 79.13-95.91%; philometroidosis – 81.30-91.16%, compared to the monitoring results. Scientists A. Hedayati et al. (2018), and N. Holembovska et al. (2024) proved the antiparasitic efficacy of povidone-iodine at 200 mg/m<sup>3</sup> for 1 hour in the destruction of *Pseudocapillaria tomentosa* in danio fish. The contamination of fish by bacterial microflora, alongside the presence of ectoparasites, was high, which further reduced productivity and posed a threat to carp health. Research indicated that the proportion of contaminated fish included *Escherichia coli* (6.25-6.75%), *Aeromonas hydrophila* (6.42-9.50%), *Aeromonas salmonicida* (5.67-7.45%) *Pseudomonas anguilliseptica* (3.27-6.85%) *Staphylococcus aureus* (5.24-6.36%), *Streptococcus iniae* (5.42-6.23%), *Listeria monocytogenes* (4.80-5.36%), *Micrococcus spp.* (5.27-7.28%) out of 100 experimental carp.

Research by F.I. Magouz et al. (2024) confirms the contamination of fish with bacteria such as *Aeromonas*, *Vibrio*, *Streptococcus*, *Pseudomonas*, *Enterococcus* and *Edwardsiella spp.*, especially at elevated water temperatures. Furthermore, an analysis of bacteria isolated from fish by researchers P. Nicholson et al. (2020) showed a high level of infestation with *A. hydrophila* concurrently with *Aeromonas spp.*, demonstrating their synergy. The obtained results provide a basis for the development and implementation of more effective strategies for the prevention and treatment of diseases.

Treatment of carp with a 0.05% iodine-based solution significantly reduced the number of fish infested with *Escherichia coli*, *Aeromonas hydrophila*, and *Pseudomonas anguilliseptica* at LLC "Ryasnianske". The number of fish contaminated with *Aeromonas salmonicida*, *Listeria monocytogenes* and *Micrococcus spp.* decreased significantly at LLC "Bdzhola". Results obtained by X. Chen et al. (2018) showed that povidone-iodine eliminates *Micropterus salmoides rhabdovirus (MSRV)* *A. hydrophila* in closed water bodies and prevents fish contamination. The maximum reduction in staphylococcal colonisation of fish was observed at PC "Shmatukha". Scientists P. Xu et al. (2021) confirmed in their studies that *Staphylococcus aureus* forms a biofilm, making it difficult to eliminate. The level of *Streptococcus iniae* contamination decreased after treatment with the experimental 0.05% agent at LLC "Bdzhola". Scientists N. Mon-On et al. (2018) proved in their studies the high efficacy of povidone-iodine in inactivating *Streptococcus spp.*



Increasing the concentration of the experimental agent to 0.1% had a positive impact on reducing bacterial contamination of carp: *E. coli* by 46.24%, *A. hydrophila* by 50.84%, *A. salmonicida* by 37.21%, *P. anguilliseptica* by 45.25%, *S. aureus* by 63.20%, *S. iniae* by 34.31%, *L. monocytogenes* by 46.15%, and *Micrococcus spp.* by 46.15%. The obtained results are confirmed by the experiment of Q. Ma *et al.* (2024) where they recommend treating fish embryos for 5-20 minutes with a povidone-iodine buffer solution to eliminate *Micropterus salmoides rhabdovirus* at a concentration of 5 mg/L.

To achieve maximum efficacy in reducing bacterial contamination, the concentration of the experimental agent was increased to 0.2%. As a result of the experiment, a reduction in fish contamination was observed: *E. coli* by 99.2%, *A. hydrophila* by 99.15%, *A. salmonicida* by 97.23%, *P. anguilliseptica* by 99.08%, *S. aureus* by 98.74%, *S. iniae* by 99.63%, *L. monocytogenes* by 98.13%, and *Micrococcus spp.* by 46.15%. The maximum values obtained in the experimental farms were considered. The results of the study by R. He *et al.* (2024) confirm the possibility of using iodine-based preparations to develop a method for controlling the transmission of infestation in closed-water bodies. As a result of the experiment, the most effective concentration of the experimental agent was determined, namely 0.2%, for the destruction of ectoparasites and bacterial microflora on the surface of carp before stocking in ponds.

## CONCLUSIONS

Carp infestation with ectoparasites *G. kobayashii* was found to be 43.32%, *L. cyprinacea* – 46.67%, and *P. lusiana* – 31.71% in fish farms. The use of a 0.2% iodine-based agent enabled the destruction of gyrodactylosis by 89.92-97.35%; lernaecosis by 79.13-95.91%; and philometroidosis by 81.30-91.16%, compared to monitoring results. As a result of the treatment of carp with the experimental agent at a concentration of 0.2%, the content of *Escherichia coli* decreased at PC “Shmatukha” by 98.96%, at LLC “Bdzhola” by 99.2%, and at LLC “Ryasnianske” by 84.32%, compared to the beginning of the experiment. The infestation with *A. hydrophila* decreased after treatment at PC “Shmatukha” by 94.51%,

at LLC “Bdzhola” by 80.28%, and at LLC “Ryasnianske” by 99.15%, compared to monitoring.

Contamination of carp with *A. salmonicida* decreased after treatment with the experimental agent at a concentration of 0.2% at PC “Shmatukha” by 97.23%, at LLC “Bdzhola” by 94.00%, and at LLC “Ryasnianske” by 79.06%, compared to monitoring results. The level of *P. anguilliseptica* colonisation decreased at PC “Shmatukha” by 99.08%, at LLC “Bdzhola” by 97.91%, and at LLC “Ryasnianske” by 99.41%. Carp infestation with *S. aureus* decreased after treatment with the iodine-based agent at PC “Shmatukha” by 92.15%, at LLC “Bdzhola” by 98.74%, and at LLC “Ryasnianske” by 93.89%, compared to initial data. The level of *Streptococcus iniae* decreased at PC “Shmatukha” by 80.90%, at LLC “Bdzhola” by 99.63%, and at LLC “Ryasnianske” by 83.30%.

The number of *L. monocytogenes* decreased at PC “Shmatukha” by 96.25%, at LLC “Bdzhola” by 96.08%, and at LLC “Ryasnianske” by 98.13%, compared to monitoring results. Carp infestation with *Micrococcus spp.* decreased after treatment with the experimental agent at PC “Shmatukha” by 93.74%, at LLC “Bdzhola” by 96.37%, and at LLC “Ryasnianske” by 92.26%. It was established that the use of a 0.2% iodine-based agent eliminates ectoparasites *G. kobayashii*, *L. cyprinacea*, *P. lusiana*, and bacterial microflora *E. coli*, *A. hydrophila*, *A. salmonicida*, *P. anguilliseptica*, *S. aureus*, *S. iniae*, *L. monocytogenes*, and *Micrococcus spp.* on the surface of carp. The perspective of further research is to determine the level of infestation of carp with ectoparasites and bacterial infestations one year after stocking in a pond.

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## CONFLICT OF INTEREST

None.

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## Результати застосування йодмісткого засобу при вирощуванні корошових риби у закритих водоймах

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**Анотація.** Метою дослідження було провести моніторинг ураження риби ектопаразитами та бактеріальними інфекціями та встановити ефективні дози нового йодмісткого засобу з метою профілактики хвороб риби. Дослідженнями встановлено ураження коропа ектопаразитами *G. kobayashii* на 43,32 %, *L. cyprinacea* – на 46,67 %, *P. lusiana* – на 31,71 % у рибних господарствах Сумської області. Обробка йодмістким засобом дала можливість знизити ступень ураження до 0,2 % в тому числі на гіродактильоз – 89,92-97,35 %; лерніозу – 79,13-95,91 %, філометроїдозу – 81,30-91,16 %, порівняно з моніторинговими результатами. При дослідженні на бактеріальні інфекції виявлено, що контамінація коропа була більше *E. coli* у ПП «Шматуха» на 8,0 %; *Aeromonas hydrophila* на 47,97 % та *Aeromonas salmonicida* – на 31,39 %, *Pseudomonas anguilliseptica* – на 19,48 %, *Streptococcus iniae* – на 13,27 %, *Micrococcus spp.* – на 38,14 % у ТОВ «Ряснянське»; *Staphylococcus aureus* – на 21,37 %, *Listeria monocytogenes* – на 11,43 % у ТОВ «Бджола» ці показники були менше ніж в інших господарствах. Після обробки йодмістким засобом контамінація риби *E. coli* знизилась у ПП «Шматуха» на 98,96 %, у ТОВ «Бджола» – на 99,2 %, у ТОВ «Ряснянське» – на 84,32 %. Обсіменіння коропа *A. hydrophila* знизилось у ПП «Шматуха» на 94,51 %, у ТОВ «Бджола» – на 80,28 %, у ТОВ «Ряснянське» – на 99,15 %; *A. salmonicida* у ПП «Шматуха» на 97,23 %, у ТОВ «Бджола» – на 94,00 %, у ТОВ «Ряснянське» – на 79,06 %; *S. aureus* у ПП «Шматуха» на 92,15 %, у ТОВ «Бджола» – на 98,74 %, у ТОВ «Ряснянське» – на 93,89 %; *S. iniae* у ПП «Шматуха» на 80,90 %, у ТОВ «Бджола» – на 99,63 %, у ТОВ «Ряснянське» – на 83,30 %; *L. monocytogenes* зменшилась у ПП «Шматуха» на 96,25 %, у ТОВ «Бджола» – на 96,08 %, у ТОВ «Ряснянське» – на 98,13 %; *Micrococcus spp.* у ПП «Шматуха» на 93,74 %, у ТОВ «Бджола» – на 96,37 %, у ТОВ «Ряснянське» – на 92,26 % порівняно з результатами моніторингу. Практичною цінністю роботи є контроль поширення та розробка профілактичних заходів для знищення ектопаразитів та бактеріальних інфекцій коропа перед висадкою у водойми

**Ключові слова:** ектопаразити риби; екстенсивність інвазії; бактеріальна мікрофлора; контроль; профілактика