Persistence factors and antibiotic susceptibility of enterobacteria isolated from various animal species

Vladimir Ermakov* and *Nikolai* Titov

Department of Epizootiology, Pathology, and Pharmacology, Samara State Agrarian University, town Ust-Kinelsky, 2, Uchebnaya St., Samara, 446442, Russian Federation

Abstract. During the study, we isolated 575 strains of enterobacteria from various animal species belonging to the genus Escherichia, Shigella, Salmonella, Klebsiella, Proteus, Providencia, Hafnia, Morganella, Enterobacter, Citrobacter, Serratia, Erwinia, Kluyvera, Yersinia. In farm animals, the amount of transient pathogenic enterobacteria Salmonella enteritidis and Yersinia enterocolitica did not exceed 0.22-0.12%. Among wild animals, the proportion of pathogenic Salmonella enteritidis and Yersinia enterocolitica did not exceed 0.24-0.11%, while Shigella dysenteriae and Shigella flexneri were isolated at a low concentration of 0.01%. In the feces of zoo animals, the amount of Salmonella enteritidis and Yersinia enterocolitica did not exceed 0.21-0.10%, while Shigella dysenteriae and Shigella flexneri were detected at the level of 0.01% of the total concentration of enterobacteria. The share of Salmonella enteritidis and Yersinia enterocolitica in domestic animals did not exceed 0.012-0.04%. Persistence factors in Salmonella enteritidis, Shigella dysenteriae and Shigella flexneri, Klebsiella oxytoca, and Yersinia enterocolitica were observed to be the highest among all isolated enterobacteria. Enterobacteria showed high resistance to benzylpenicillin from the group of natural penicillins to streptomycin, cephalothin from the group of cephalosporins of the first generation, polymyxin B, ofloxacin (tarivid), and metronidazole. Carbenicillin from the group of carboxypenicillins and piperacillin from the group of ureidopenicillins, kanamycin, amikacin, and gentamicin, cefepime from the group of IV generation cephalosporins, tetracycline, doxycycline and chloramphenicol, nalidixic acid, trimethoprim showed the highest antimicrobial activity against all cultures of enterobacteria isolated in this study.

1 Introduction

Recently, the role of the etiological diagnosis of infectious diseases has increased significantly, which requires the study of new and improvement of existing microbiological methods. Interest in biotechnological research has increased in terms of the etiological laboratory diagnosis of various diseases of a non-contagious and infectious nature. The incidence of so-called opportunistic infections caused by opportunistic microorganisms remains quite high in humans and animals [1, 9, 10, 4].

Leading microbiologists note that everywhere there is an activation of opportunistic bacteria and fungi, which are characterized by the absence of nosological specificity and localization of the infectious process. Opportunistic enterobacteria of the Enterobacteriaceae family are one of the main causative agents of opportunistic infections that can cause pathology of the gastrointestinal tract, meningitis, encephalitis, multiple neuritides, pyelitis, pyelonephritis, cystitis, cholecystitis, peritonitis, appendicitis, pancreatitis, pneumonia, nasopharyngitis, otitis, conjunctivitis, ophthalmitis, toxic-septic complications. This pathology is characterized by a polymorphism of clinical manifestations, associated not so much with the epidemic or epizootic situation, but with the age and state of the patient's defenses. Opportunistic enterobacteria, under certain conditions, also play an active role in the etiology of acute intestinal infections in humans and animals [5, 6, 7, 8, 12].

Currently, several new groups (genera) of enterobacteria have been introduced into the Enterobacteriaceae family. These are the bacteria Cedecea, Ewingella, Kluyvera, Lecrecia, Moellerella, Pantoea, Pragia, Rahnella, Tatumella, Xenorhabdus, and Jokenella. The clinical significance of these new members of the Enterobacteriaceae family is under investigation. The biological properties of these enterobacteria are being studied, and methods for their isolation and identification are being developed [2, 3, 11].

2 Materials and methods

During the study, 575 enterobacteria isolates obtained from the intestinal contents of various animal species were experimental material. Among the farm animals involved cows, sheep, goats, pigs, horses, and birds (chickens, guinea fowl, ducks, and geese). Among domestic animals, the material was obtained from cats

* Corresponding author: Vladimir_21_2010@mail.ru

and cats, dogs, ferrets, raccoons, and chinchillas. The material was also obtained from wild and zoo animals such as wild boars, elks, foxes, ponies, and camels.

The suspension of the material was sown on elective and differential diagnostic nutrient media. The grown cultures of enterobacteria were identified by specific biological properties. Enterobacteria were also identified using Escherichiosis, Shigella, Klebsiella, Proteus phage, and a set of Salmonella phages.

Determination of pathogenicity factors of enterobacteria was carried out according to generally accepted methods. Hemolytic and gelatinase, and catalase activity of cultures of enterobacteria were detected during the cultivation of microorganisms on enriched media and by setting up biochemical tests. The protease activity of enterobacteria cultures was determined by the decrease in albumin after co-incubation with the studied microorganisms by the biuret method. Among the persistence factors of enterobacteria, antilysozyme and anticarnosine activity were determined by the photometric method. The ability of enterobacteria to form biofilms was determined by the degree of binding of crystal violet by microorganisms in polystyrene plates.

Serological properties of enterobacteria were studied in reactions with specific diagnostic sera in reactions, agglutination, complement fixation, and precipitation. The determination of the sensitivity to antimicrobial drugs isolated by us from various animal isolates of enterobacteria was carried out by the disk diffusion method on AGV medium and Muller-Hinton agar, as well as by the method of serial dilutions in MPB broth and on Endo agar. The results obtained during the study were processed statistically according to the generally accepted method using a PC Pentium using the Microsoft Office Excel application.

3 Results and discussion

During the research, 215 intestinal isolates of enterobacteria were isolated from farm animals - cows, sheep, goats, pigs, horses, and poultry (chickens, guinea fowl, ducks, and geese). We found that the total number of identified enterobacteria in 1 g of feces in farm animals was $1.159510^{x}106\pm1.32$ (Table 1).

Table 1. Cultures of enterobacteria isolated from farm animals.

Enterobacteria, pure culture	Number of enterobacteria, 10^n	Correlation with the total number of enterobacteria, %
Escherichia coli	$5.43^{x}10^{5}\pm0.82$	46.83
Shigella dysenteriae	not identified	not identified
Shigella flexneri	not identified	not identified
Salmonella enteritidis	$2.54^{x}10^{3}\pm0.26$	022
Klebsiella oxytoca	$3.47^{x}10^{4}\pm0.68$	2.99
Proteus vulgaris	$3.59^{x}10^{3}\pm0.61$	0.31
Providencia alcalifaciens	$3.74^{x}10^{4}\pm0.13$	3.22
Hafnia alvei	$4.78^{x}10^{4}\pm0.47$	4.12
Morganella morganii	$4.72^{x}10^{3}\pm0.23$	0.41
Enterobacter cloacae	$4.54^{x}10^{4}\pm0.26$	3.92
Citrobacter freundii	$2.37^{x}10^{4}\pm0.53$	2.04
Serratia marcescens	$3.55^{x}10^{5}\pm0.13$	30.62
Erwinia amylovora	$3.28^{x}10^{4}\pm0.16$	2.83
Kluyvera cryocrescens	$2.75^{x}10^{4}\pm0.15$	2.37
Yersinia enterocolitica	$1.36^{x}10^{3}\pm0.12$	0.12

The species composition of enterobacteria isolated from agricultural ones was dominated by representatives of the genus Escherichia coli 46.83% and Serratia marcescens 30.62%. During the research, 105 intestinal isolates of enterobacteria were isolated from wild animals, namely wild boars, elks, and foxes. We found that the total number of identified enterobacteria in 1 g of feces in wild animals was $1.155454^{x}106\pm1.18$ (Table 2).

Table 2. Enterobacteria cultures isolated from wild animals.

Enterobacteria, pure culture	Number of enterobacteria, 10^n	Correlation with the total number of enterobacteria, %
Escherichia coli	$4.77x10^{5}\pm0.38$	41.28
Shigella dysenteriae	$1.48\ x10^{2}\pm0.72$	0.01
Shigella flexneri	$1.06\ x10^{2}\pm0.38$	0.01
Salmonella enteritidis	$2.83x10^{3}\pm0.33$	0.24
Klebsiella oxytoca	$2.84x10^{4}\pm0.37$	2.46
Proteus vulgaris	$4.37x10^{3}\pm0.53$	0.38
Providencia alcalifaciens	$3.82x10^{4}\pm0.35$	3.32
Hafnia alvei	$4.19x10^{4}\pm0.67$	3.62
Morganella morganii	$4.62x10^{3}\pm0.24$	0.40
Enterobacter cloacae	$5.12x10^{4}\pm0.32$	4.43
Citrobacter freundii	$3.16x10^{4}\pm0.42$	2.73
Serratia marcescens	$4.06x10^{5}\pm0.16$	35.14
Erwinia amylovora	$3.66x10^{4}\pm0.64$	3.17
Kluyvera cryocrescens	$3.12x10^{4}\pm0.36$	2.70
Yersinia enterocolitica	$1.28x10^{3}\pm0.32$	0.11

The species composition of enterobacteria isolated from wild animals was dominated by representatives of the genus Escherichia coli 41.28% and Serratia marcescens 35.14%. During the research, 85 intestinal isolates of enterobacteria were isolated from zoo animals, namely, ponies, and camels. We found that the

total number of identified enterobacteria in 1 g of feces in zoo animals was 1.586852x106±1.46 (Table 3).

Table 3. Cultures of enterobacteria isolated from zoo animals.

Enterobacteria, pure culture	Number of enterobacteria, 10^n	Correlation with the total number of enterobacteria, %
Escherichia coli	$5.24x10^5$±1.26	33.03
Shigella dysenteriae	1.28 $x10^2$±0.94	0.01
Shigella flexneri	1.64 $x10^2$±0.76	0.01
Salmonella enteritidis	$3.36x10^3$±0.58	0.21
Klebsiella oxytoca	$3.88x10^4$±0.82	2.44
Proteus vulgaris	$5.94x10^3$±1.46	0.37
Providencia alcalifaciens	$4.16x10^4$±0.92	2.62
Hafnia alvei	$6.32x10^4$±1.56	3.98
Morganella morganii	$6.12x10^3$±0.88	0.39
Enterobacter cloacae	$7.48x10^4$±1.58	4.71
Citrobacter freundii	$4.86x10^4$±1.26	3.06
Serratia marcescens	$6.74x10^5$±1.62	42.48
Erwinia amylovora	$4.78x10^4$±1.38	3.01
Kluyvera cryocrescens	$5.68x10^4$±1.24	3.58
Yersinia enterocolitica	$1.54x10^3$±0.72	0.1

The species composition of enterobacteria isolated from zoo animals was dominated by representatives of the genus Escherichia coli 33.03% and Serratia marcescens 42.48%. At the same time, the proportion of serrations was higher compared to Escherichia. During the research, we isolated 180 intestinal isolates of enterobacteria from domestic animals, namely, cats and cats, dogs, ferrets, raccoons, and chinchillas. We found that the total number of identified enterobacteria in 1 g of feces in domestic animals was 1.529452x106±1.32 (Table 4).

Table 4. Cultures of enterobacteria isolated from domestic animals

Enterobacteria, pure culture	Number of enterobacteria, 10^n	Correlation with the total number of enterobacteria, %
Escherichia coli	$6.72x10^5$±1.16	43.94
Shigella dysenteriae	$0.62x10^2$±0.44	0.003
Shigella flexneri	$0.86x10^2$±0.68	0.005
Salmonella enteritidis	$1.84x10^3$±0.48	0.012
Klebsiella oxytoca	$4.78x10^4$±0.82	3.12
Proteus vulgaris	$4.62x10^3$±1.18	0.30
Providencia alcalifaciens	$4.28x10^4$±0.52	2.80
Hafnia alvei	$5.68x10^4$±0.85	3.71
Morganella morganii	$4.12x10^3$±0.46	0.27
Enterobacter cloacae	$5.74x10^4$±0.82	3.75
Citrobacter freundii	$4.22x10^4$±0.66	2.76
Serratia marcescens	$5.18x10^5$±1.48	33.87
Erwinia amylovora	$4.86x10^4$±1.08	3.18
Kluyvera cryocrescens	$3.42x10^4$±0.55	2.24
Yersinia enterocolitica	$0.58x10^3$±0.26	0.04

The species composition of enterobacteria isolated from domestic animals was dominated by representatives of the genus Escherichia coli 43.94% and Serratia marcescens 33.87%. Enterobacteria isolated by us from various animal species were identified by specific biological properties. In the process of identifying persistence factors in enterobacteria isolated from various animals, we determined the indicators of the manifestation of antilysozyme, anticarnosine activity, and the ability of enterobacteria to biofilm formation (Table 5).

Table 5. Persistence factors of enterobacteria isolated from farm animals.

Enterobacteria	Persistence Factors		
	Antilysozyme activity µg/ml	Anticarnosine activity mg/ml	Ability of biofilm formation, %
Escherichia coli	3.28±0.12	3.06±0.08	72.4±5.2
Serratia marcescens	2.86±0.14	2.94±0.12	58.7±3.6
Kluyvera cryocrescens	2.74±0.16	2.88±0.12	49.6±2.8
Providencia alcallifaciens	2.12±0.06	2.04±0.04	58.2±3.4
Morganella morganii	2.04±0.04	1.74±0.08	52.8±2.6
Hafnia alvei	2.44±0.32	2.86±0.46	58.6±2.8
Erwinia amylovora	2.06±0.24	1.34±0.22	64.6±3.2
Klebsiella oxytoca	3.68±0.37	2.52±0.18	54.6±3.4
Proteus vulgaris	2.34±0.14	2.78±0.12	62.8±2.4
Enterobacter cloacae	2.78±0.18	2.94±0.24	66.4±4.8
Citrobacter freundii	2.54±0.12	3.08±0.16	48.2±2.8
Salmonella enteritidis	3.86±0.86	2.18±0.72	60.8±5.6
Yersinia enterocolitica	1.46±0.26	3.38±0.48	56.2±3.8

Enterobacteria in farm animals Salmonella Enteritidis and Klebsiella oxytoca showed the highest rates of antilysozyme activity. And representatives of Yersinia enterocolitica had higher anticarnosine activity. At the same time, representatives of Escherichia coli showed

the highest ability to biofilm formation. Yersinia enterocolitica, on the contrary, showed minimal anti-lysozyme activity compared to other enterobacteria. Erwinias and morganellas showed minimal anticarnosine activity, while citrobacters and kluivers had the lowest ability to biofilm formation. Table 6 shows the persistence factors of enterobacteria isolated from wild animals.

Table 6. Persistence factors for enterobacteria isolated from wild animals.

Enterobacteria	Persistence Factors		
	Antilysozyme activity μg/ml	Anticarnosine activity mg/ml	Ability of biofilm formation, %
Escherichia coli	2.54±0.05	2.48±0.04	68.4±4.8
Shigella dysenteriae	4.38±0.68	3.76±0.88	74.8±6.4
Shigella flexneri	3.16±0.48	3.54±0.36	78.6±5.2
Serratia marcescens	2.12±0.04	2.26±0.02	52.3±4.2
Kluyvera cryocrescens	2.22±0.06	2.56±0.08	45.7±1.5
Providencia alcallifaciens	2.37±0.08	2.28±0.07	42.8±2.3
Morganella morganii	1.14±0.02	1.25±0.03	33.5±1.6
Hafnia alvei	1.08±0.03	1.06±0.04	38.7±1.3
Erwinia amylovora	not identified	not identified	43.2±1.4
Klebsiella oxytoca	2.63±0.07	3.24±0.25	74.3±3.8
Proteus vulgaris	2.98±0.08	2.43±0.16	69.8±3.5
Enterobacter cloacae	2.05±0.05	1.54±0.05	52.6±1.9
Citrobacter freundii	1.32±0.04	1.04±0.02	40.6±1.2
Salmonella enteritidis	3.07±0.23	2.77±0.26	86.4±4.2
Yersinia enterocolitica	2.64±0.18	2.34±0.17	61.7±2.7

The following Shigella showed the highest levels of antilysozyme activity and anticarnosine activity in wild animals: Shigella dysenteriae and Shigella flexneri. In these species of Shigella, high ability for biofilm formation was also observed. Salmonella enteritidis also had high anti-lysozyme and anticarnosine activity and surpassed pathogenic Shigella representatives Shigella dysenteriae and Shigella flexneri in biofilm formation ability.

Hafnia showed minimal antilysozyme and anticarnosine activity compared to other enterobacteria. Morganella also had insignificant antilysozyme activity, while citrobactors also showed low anticarnosine activity. Hafnia and morganella had a low ability to biofilm formation, compared with other enterobacteria. At the same time, the anti-lysozyme and anti-carnosine activity in enterobacteria Erwinia amylovora could not be revealed, and their ability to biofilm formation was also insignificant. Table 7 shows the persistence factors of enterobacteria isolated from zoo animals.

Table 7. Persistence factors for enterobacteria isolated from zoo animals.

Enterobacteria	Persistence Factors		
	Antilysozyme activity μg/ml	Anticarnosine activity mg/ml	Ability of biofilm formation, %
Escherichia coli	2.94±0.38	2.52±0.12	66.8±3.4
Shigella dysenteriae	1.36±0.44	2.24±0.86	62.6±2.6
Shigella flexneri	1.84±0.52	1.32±0.88	70.8±2.2
Serratia marcescens	1.52±0.12	2.58±0.56	62.6±2.4
Kluyvera cryocrescens	1.32±0.22	1.56±0.34	54.2±3.6
Providencia alcallifaciens	1.74±0.18	1.14±0.22	63.8±2.8
Morganella morganii	1.88±0.26	2.38±0.44	64.4±3.8
Hafnia alvei	1.46±0.12	1.54±0.10	60.2±3.4
Erwinia amylovora	2.72±0.56	1.78±0.68	74.8±5.8
Klebsiella oxytoca	4.56±3,84	3.98±1.36	80.8±7.2
Proteus vulgaris	4.82±1.72	3.12±1.84	76.6±3.2
Enterobacter cloacae	1.73±0.26	1.52±0.10	70.4±2.4
Citrobacter freundii	1.18±0.08	2.34±0.82	58.4±3.6
Salmonella enteritidis	5.18±2.32	3.72±0.98	52.6±2.4
Yersinia enterocolitica	6.48±2.84	4.76±2.18	66.8±1.6

The indicators of antilysozyme and anticarnosine activity were the highest in pathogenic Yersinia enterocolitica and Salmonella enteritidis. At the same time, in Klebsiella oxytoca, the anticarnosine activity was slightly higher than in Salmonella enteritidis. Klebsiella oxytoca and Proteus Vulgaris were the most capable of biofilm formation. The ability for biofilm formation was also high in representatives of Erwinia amylovora and Enterobacter cloacae.

Indicators of anti-lysozyme activity in enterobacteria Citrobacter freundii, anticarnosine activity in bacteria Shigella flexneri were the lowest compared to other enterobacteria. Salmonella (Salmonella enteritidis) and Kluyvera (Kluyvera cryocrescens) had a slight ability to biofilm formation, compared with other enterobacteria. Table 8 shows the persistence factors of enterobacteria isolated from domestic animals.

Enterobacteria of the genus Klebsiella oxytoca and Salmonella enteritidis showed the highest antilysozyme and anticarnosine activity compared to other members of the Enterobacteriaceae family. Escherichia coli and Klebsiella Klebsiella oxytoca showed the highest ability for biofilm formation. The lowest values of antilysozyme activity were registered by us in enterobacter Enterobacter cloacae, and anticarnosine activity in Morganella morganii. At the same time, pathogenic Salmonella enteritidis showed the lowest ability to biofilm formation compared to other enterobacteria.

Table 8. Persistence factors for Enterobacteriaceae isolated from domestic animals.

Enterobacteria	Persistence Factors		
	Antilysozyme activity μg/ml	Anticarnosine activity mg/ml	Ability of biofilm formation, %
Escherichia coli	2.04±0.08	2.34±0.12	80.6±6.8
Shigella dysenteriae	3.36±1.18	2.44±1.22	74.6±3.4
Shigella flexneri	3.48±1.22	3.78±1.46	72.8±4.8
Serratia marcescens	1.58±0.10	1.32±0.18	60.7±4.2
Kluyvera cryocrescens	2.06±0.34	1.66±0.88	56.8±3.4
Providencia alcallifaciens	1.54±0.34	1.84±0.08	64.8±2.6
Morganella morganii	1.34±0.12	1.26±0.18	58.4±5.8
Hafnia alvei	1,38±0.14	1.44±0.36	52.8±3.2
Erwinia amylovora	1,44±0.52	1.92±0.80	62.2±4.6
Klebsiella oxytoca	6,36±2.78	4.18±1.74	80.2±5.4
Proteus vulgaris	3,76±0.33	3.24±0.48	78.2±3.2
Enterobacter cloacae	1,18±0.12	3.14±0.88	74.4±6.4
Citrobacter freundii	1,76±0.34	2.18±0.94	56.2±3.2
Salmonella enteritidis	6,18±6,74	5,74±3,96	48,2±3,4
Yersinia enterocolitica	4,73±2,16	3,06±1,26	62,8±5,6

Pathogenic Yersinia enterocolitica, Shigella dysenteriae, and Shigella flexneri also showed relatively high antilosizyme, anticarnosine activity, and ability to biofilm formation against the background of persistence indicators of other enterobacteria cultures. However, the biofilm-forming ability of Yersinia enterocolitica was lower than that of Proteus Vulgaris. Trimethoprim showed the highest antimicrobial activity against all cultures of enterobacteria isolated by us. Most enterobacteria were resistant to metronidazole. At the same time, pathogenic Shigella dysenteriae, S. flexneri, Salmonella Enteritidis, and Yersinia enterocolitica were also more sensitive to trimethoprim (Table 9).

As a result, we found that Escherichia coli are highly sensitive to carbenicillin and piperacillin, kanamycin, amikacin, cefepime, cefotaxime, cefozopran, polymyxin B, chloramphenicol, nalidixic acid, ciprofloxacin, trimethoprim. Escherichia coli are relatively resistant to benzylpenicillin, gentamicin, cephalothin, doxycycline, ofloxacin, metronidazole.

Shigella dysenteriae and S. flexneri are sensitive to carbenicillin and piperacillin, kanamycin, amikacin, cefepime, cefozopran, cefquin, chloramphenicol, ciprofloxacin, trimethoprim. Shigella dysenteriae and S. flexneri are relatively resistant to benzylpenicillin, streptomycin, cephalothin, polymyxin B, ofloxacin, metronidazole.

Salmonella enteritidis (S. enterica subsp. enterica enteritidis) are sensitive to carbenicillin and piperacillin, kanamycin, amikacin, cefepime, chloramphenicol, nalidixic acid, co-trimoxazole, and trimethoprim. Salmonella enteritidis relatively resistant to benzylpenicillin, streptomycin, cephalothin, polymyxin B, ciprofloxacin, metronidazole.

Klebsiella oxytoca is sensitive to carbenicillin and piperacillin, gentamicin and kanamycin, cefepime, chloramphenicol, nalidixic acid, co-trimoxazole, and trimethoprim. Klebsiella oxytoca is relatively resistant to benzylpenicillin, amikacin, cephalothin, dioxycycline, ofloxacin, furadonin, and metronidazole.

Proteus Vulgaris is sensitive to carbenicillin and piperacillin, gentamicin and kanamycin, cefepime, tetracycline, chloramphenicol, nalidixic acid, ciprofloxacin, cotrimoxazole, and trimethoprim. Proteus Vulgaris is relatively resistant to benzylpenicillin, streptomycin, amikacin, cephalothin, polymyxin B, ofloxacin, metronidazole, furadonin.

Table 9. Antibiotic susceptibility of enterobacteria to metronidazole, furadonin, cotrimoxazole, and trimethoprim (growth inhibition zone value (mm).

Enterobacteria, pure culture	Antimicrobials			
	metronidazole	furadonin (nitrofurantoin)	co-trimoxazole	trimethoprim
Escherichia coli	8±0.8	18±1.2	17±0.5	26±2.3
Shigella dysenteriae	6±0.5	22±1.9	20±1.2	28±2.8
Shigella flexneri	5±0.4	26±2.2	25±1.5	30±2.6
Salmonella enteritidis	8±1.4	15±0.8	20±1.6	22±1.8
Klebsiella oxytoca	10±1.6	8±1.8	25±3.2	24±1.5
Proteus vulgaris	12±1.8	12±1.3	25±3.8	28±2.5
Providencia alcalifaciens	8±0.8	20±1.4	25±2.6	25±1.8
Hafnia alvei	10±1.2	18±2.2	23±2.5	23±2.0
Morganella morganii	12±1.5	10±3.5	27±4.5	26±1.7
Enterobacter cloacae	10±1.4	8±1.4	26±1.9	27±2.2
Citrobacter freundii	8±0.5	20±1.6	25±1.5	30±2.4
Serratia marcescens	8±1.2	19±0.6	22±0.7	35±3.4
Erwinia amylovora	10±2.2	12±1.3	37±6.2	34±2.6
Kluyvera cryocrescens	12±2.6	18±1.2	21±0.9	32±3.6
Yersinia enterocolitica	10±1.5	28±0.6	21±0.7	30±2.7

Providencia alcalifaciens are sensitive to carbenicillin and piperacillin, amikacin, cefepime, tetracycline, cmprofloxacin, cotrimoxazole, and trimethoprim. Providencia alcalifaciens is relatively resistant to benzylpenicillin, streptomycin, kanamycin, cephalothin, polymyxin B, and metronidazole.

Hafnia alvei are sensitive to carbenicillin and piperacillin, gentamicin, amikacin, cefepime, chloramphenicol, nalidixic acid, co-trimoxazole, and trimethoprim. Hafnia alvei are relatively resistant to benzylpenicillin, streptomycin, kanamycin, cephalothin, polymyxin B, ciprofloxacin, metronidazole.

Morganella morganii is susceptible to carbenicillin and piperacillin, gentamicin, kanamycin, cefepime, cefquin, cefosoprane, doxycycline, chloramphenicol, ciprofloxacin, co-trimoxazole, and trimethoprim. Morganella morganii is relatively resistant to benzylpenicillin, streptomycin, amikacin, cephalothin, polymyxin B, ofloxacin, metronidazole, furadonin.

Enterobacter cloacae are sensitive to carbenicillin and piperacillin, kanamycin, amikacin, cefepime, doxycycline, nalidixic acid, co-trimoxazole, and trimethoprim. Enterobacter cloacae are relatively resistant to benzylpenicillin, streptomycin, cephalothin, polymyxin B, ciprofloxacin, furadonin, metronidazole.

Citrobacter freundii are sensitive to piperacillin, amikacin, cefepime, doxycycline, ofloxacin, and trimethoprim. Citrobacter freundii is relatively resistant to benzylpenicillin, streptomycin, cephalothin, polymyxin B, ciprofloxacin, and metronidazole.

Serratia marcescens are sensitive to piperacillin, gentamicin, cefepime, tetracycline, nalidixic acid, and trimethoprim. Serratia marcescens is relatively resistant to benzylpenicillin, amikacin, cephalothin, polymyxin B, ofloxacin, and metronidazole.

Erwinia amylovora is sensitive to piperacillin, kanamycin, cefepime, cefquin, chloramphenicol, nalidixic acid, co-trimoxazole, and trimethoprim. Erwinia amylovora relatively resistant to benzylpenicillin, gentamicin, cephalothin, polymyxin B, ofloxacin, metronidazole, furadonin.

Kluyvera cryocrescens are highly sensitive to piperacillin, amikacin, cefepime, chloramphenicol, ofloxacin, and trimethoprim. Kluyvera cryocrescens are relatively resistant to benzylpenicillin, streptomycin, cephalothin, polymyxin B, and metronidazole.

Yersinia enterocolitica is sensitive to piperacillin, gentamicin, cefepime, doxycycline, chloramphenicol, ciprofloxacin, nalidixic acid, trimethoprim, furadonin. Yersinia enterocolitica is relatively resistant to ampicillin, benzylpenicillin, streptomycin, cephalothin, tetracycline, polymyxin B, ofloxacin, metronidazole.

4 Conclusion

During the study, we isolated 575 strains of enterobacteria from various animal species belonging to the genus Escherichia, Shigella, Salmonella, Klebsiella, Proteus, Providencia, Hafnia, Morganella, Enterobacter, Citrobacter, Serratia, Erwinia, Kluyvera, Yersinia. In agricultural animals, the number of transient pathogenic enterobacteria Salmonella enteritidis and Yersinia enterocolitica did not exceed 0.22–0.12%, respectively, and Shigella dysenteriae and Shigella flexneri were not isolated. Among wild animals, the proportion of pathogenic Salmonella enteritidis and Yersinia enterocolitica did not exceed 0.24–0.11%, respectively, while Shigella dysenteriae and Shigella flexneri were isolated in a small concentration of 0.01%. In the feces of zoo animals, the amount of Salmonella enteritidis and Yersinia enterocolitica did not exceed 0.21-0.10%, respectively, while Shigella dysenteriae and Shigella flexneri were detected at the level of 0.01% of the total concentration of enterobacteria. The proportion of Salmonella enteritidis and Yersinia enterocolitica in domestic animals did not exceed 0.012-0.04%, respectively, and was the smallest compared to other animal species. At the same time, Shigella dysenteriae and Shigella flexneri were found in domestic animals at a low concentration of 0.003 and 0.005% of the total number of enterobacteria compared to wild and zoo animals.

Persistence factors in Salmonella enteritidis, Shigella dysenteriae and Shigella flexneri, Klebsiella oxytoca, and Yersinia enterocolitica were observed to be the highest among all isolated enterobacteria. Enterobacteria, having persistence factors, can survive (survive) in the macroorganism of humans and animals for an unlimited time, protecting themselves from cellular and humoral factors of nonspecific defense of the macroorganism. At the same time, the presence of persistence factors in enterobacteria allows exhibiting pathogenic properties.

Enterobacteria showed high resistance to benzylpenicillin from the group of natural penicillins, streptomycin, cephalothin from the group of cephalosporins of the first generation, to polymyxin B, to ofloxacin (tarivid) and metronidazole. Carbenicillin from the group of carboxypenicillins and piperacillin from the group of ureidopenicillins, kanamycin, amikacin, and gentamicin, cefepime from the group of IV generation cephalosporins, tetracycline, doxycycline and chloramphenicol, nalidixic acid, trimethoprim showed the highest antimicrobial activity against all cultures of enterobacteria isolated by us.

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