DOI: 10.12731/2658-6649-2022-14-5-63-76
UDC 591.111.1:636.5.034

DYNAMICS OF WBC INDICES IN POULTRY FOLLOWING ENROFLOXACIN ADMINISTRATION: COMPARATIVE ANALYSIS

A.A. Moiseeva, A.A. Prisnyi, V.N. Skvortsov

The goal of our research was to assess the effect of Enrofloxacin (fluoroquinolone antibacterial drug) on WBC indices of different kinds of poultry at young age. In order to study the dynamics we performed two series of experiments employing groups as follows: Group 1 – control group (one-day-old chicks, receiving pure drinking water), Group 2 – experimental group (one-day-old chicks, receiving Enrofloxacin via drinking water at concentration 200 g/L for 10 consecutive days), Groups 3 and 4 were made with one-day-old ducklings, the experiment design was the same as with chicks. Blood samples were drawn from every bird on Day 1, Day 3, Day 5, Day 7 and Day 9 after the drug withdrawal. We performed differential leukocyte count, leukogram was made and we also calculated leukocyte (hematological) indices. The data analysis showed reliable changes of blood indices both in chicks and in ducklings. The greatest changes in the results of both experimental groups as compared to the control groups were observed on Day 7, but they were not lasting. We observed more pronounced and lasting changes in the leukogram of Group 2, while duckling blood showed reliable changes of leukocyte indices. But all in all dynamics in WBC indices that we observed did not show toxic effect of the drug on bird organism.

Keywords: *poultry; antibacterial drugs; fluoroquinolones; enrofloxacin; blood; WBC*

For citation. *Moiseeva A.A., Prisnyi A.A., Skvortsov V.N. Dynamics of WBC Indices in Poultry Following Enrofloxacin Administration: Comparative Analysis. Siberian Journal of Life Sciences and Agriculture, 2022, vol. 14, no. 5, pp. 63-76. DOI: 10.12731/2658-6649-2022-14-5-63-76*

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ИЗМЕНЕНИЯ ПОКАЗАТЕЛЕЙ БЕЛОЙ КРОВИ У ПТИЦ РАЗНЫХ ВИДОВ ПОСЛЕ ИСПОЛЬЗОВАНИЯ ЭНРОФЛОКСАЦИНА

А.А. Моисеева, А.А. Присный, В.Н. Скворцов

Исследование проведено с целью оценки воздействия химиотерапевтического антибактериального препарата группы фторхинолонов энрофлок-

сацина на показатели белой крови у птиц раннего возраста разных видов. Для изучения динамики проведено две серии опытов, в которых были задействованы следующие группы: 1 – контроль (цыплята суточного, возраста получавшие чистую воду), 2 – опыт (цыплята суточного возраста получали с водой энрофлоксацин в дозе 200 мг/л в течение 10 дней), группы 3 и 4 сформированы из утят суточного возраста, схема опыта аналогична ранее описанной. Отбор образцов крови у всех подопытных птиц проводили на 1, 3, 5, 7 и 9 сутки после отмены препарата. Осуществляли дифференциальный подсчет лейкоцитов, лейкоцитарной формулы и лейкоцитарных индексов. Анализ полученных данных выявил достоверные сдвиги показателей, как в крови опытных цыплят, так и утят. Наибольшие отклонения результатов, полученных во всех опытных группах относительно контрольных значений, выявлены на седьмые сутки, что, тем не менее, не было продолжительным явлением. В группе 2 обнаружены более выраженные и длительные изменения данных лейкоцитарной формулы, в свою очередь в крови утят выявлены достоверные отличия лейкоцитарных индексов. Однако, в целом, зафиксированная динамика в показателях белой крови не отражала токсического воздействия препарата на организм птиц.

Ключевые слова: *сельскохозяйственная птица; антимикробные препараты; фторхинолоны; энрофлоксацин; кровь; лейкоциты*

Для цитирования. *Моисеева А.А., Присный А.А., Скворцов В.Н. Сравнительный анализ изменения показателей белой крови у птиц разных видов после использования энрофлоксацина // Siberian Journal of Life Sciences and Agriculture. 2022. Т. 14, №5. С. 63-76. DOI: 10.12731/2658-6649-2022-14-5-63-76*

Introduction

Fluoroquinolones (FQs) are a class of antibacterial drugs, designed for chemotherapy, very special in that this class of drugs frequently expands due to invention of new members [1]. Fluoroquinolones are used for treating humans for infections [2, 3], but nowadays they are also commonly used in veterinary medicine [4, 5, 6]. This class of antimicrobials is especially popular for therapy of respiratory and gastrointestinal infections in poultry [7].

Fluoroquinolone drugs differ from other antibacterial drugs by their unique double mechanism of action and also good pharmacokinetic qualities [8, 9]. Their method of killing pathogenic microorganisms is concentration dependent and optimal therapeutic effect is achieved when high doses of fluoroquinolones are introduced into organism within a short period of time. Such dose-dependent action is associated with relatively long postantibiotic effect, character-

istic of this class of drugs, which presents an important advantage over other antimicrobials [10].

Fluoroquinolones are employed in poultry farming due to their broad-spectrum activity against both Gram-positive and Gram-negative pathogenic microorganisms such as *Salmonella typhimurium*, *Campylobacter jejuni*, *Escherichia coli*, affecting poultry at young age and old age alike [11]. There is of course a clash of opinions on what antibacterial drugs to use in poultry farms but apart from fluoroquinolones there are no other highly effective prophylactic and therapeutic agents regarding a number of bacterial infections. It was proven statistically that almost half of all mortalities in commercial poultry population occur in the first 24 hours of their lives and over 50% of poultry population die in massive outbreaks of microbial infections, first of all *Escherichia coli* [12, 13, 14]. Besides there are other dangerous intestinal pathogenic bacteria, for instance *Salmonella enterica*, capable of evading the immune response and replicating in host cells, resulting in systemic infections [15]. In order to contain microbial infections among poultry population veterinary personnel employs Enrofloxacin since it was designed exclusively for veterinary use, mainly for commercial poultry industry [16, 17].

Enrofloxacin is an antibacterial chemotherapeutic medicinal drug with broad-spectrum activity, used for therapy of respiratory tract and intestinal tract infections in poultry [18]. The drug is known to inhibit DNA gyrase in bacterial cells, it boasts increased activity against mycoplasma, Gram-positive bacteria and Gram-negative bacteria [19]. Enrofloxacin is capable of penetrating into and accumulating in phagocytic cells, which is very important in managing systemic infections, such as the above-mentioned salmonellosis [20].

Despite well-known antibacterial properties of Enrofloxacin and its prevalence in veterinary medicine, associated with such properties, some physiological aspects of its effect on organism of different kinds of poultry at different ages still remain little known. For instance there are few reports on the effect of Enrofloxacin on WBC indices of chickens and ducklings. That is the reason why we address this very problem.

Materials and Methods

In the course of our research we performed two series of experiments employing chickens and ducklings, in accordance with the method of analogous groups. The first series included studies of blood indices in one-day-old Hisex Brown chicks, allocated in two groups: control group (Group 1) received pure drinking water and experimental group (Group 2) received Enrofloxacin via

drinking water at concentration 200 g/L for 10 consecutive days. The dosage of 200 mg/L that we applied in our research was chosen in accordance with practical policies of Russian Academy of Science. The experiments in the second series followed the same experiment design: one-day-old ducklings of breed Bashkir were allocated in two groups: Group 3 was assigned as control group and Group 4 was assigned as the experimental group.

Blood samples were collected by cardiac puncture on Day 1, Day 3, Day 5, Day 7 and Day 9 after the withdrawal of Enrofloxacin.

The studies of WBC indices included leukocyte count (computation in Goryaev's chamber), count of different white blood cell types (eosinophils, basophils, pseudoeosinophils, monocytes and lymphocytes) in blood smear, stained by Romanovskiy-Giemza stain, and also calculation of leukocytic (hematological) indices by applying computational method with the following formulae:

Krebs Index (KI):

$$KI = \frac{PE}{L}$$

PE, pseudoeosinophils (%); L, lymphocytes (%).

Leukocyte Index (LI):

$$LI = \frac{L}{PE}$$

PE, pseudoeosinophils (%); L, lymphocytes (%).

Index of Immunoreactivity (IIR):

$$IIR = \frac{L + E}{M}$$

L, lymphocytes (%); M, monocytes (%); E, eosinophils (%).

Leukocyte Index of Intoxication (LII):

$$LII = \frac{PE}{B + E + L + M}$$

PE, pseudoeosinophils (%); B, basophils (%); E, eosinophils (%); L, lymphocytes (%); M, monocytes (%).

The statistical analysis of the digital data was performed using SPSS Statistic 17.0 software, reliability of the results was checked with the help of Mann-Whitney nonparametric test.

Result and Discussion

Evaluation of hematological profile in poultry serves as an indicator of physiological and pathophysiological state. Moreover it may serve as a unique tool

for monitoring the effect of various drugs on organism and detection of their yet unknown effects [21, 22].

There have been reported a few cases, after fluoroquinolone administration in mammals, of adverse hematologic reactions, such as erythrocytosis or leukopenia. Then there are reports of fluoroquinolones' detrimental effect on vital organs [23], which is manifested in changes of hematological indices. Nevertheless the results we registered in our research show the absence of significant toxic effect of Enrofloxacin on organism of birds. We only observed a singular increase by 16% in leukocyte count in chicken blood on Day 3 after the drug withdrawal.

Remarkably the changes in leukogram were more pronounced in Group 2 (Table 1, 2). Thus reliable increases in the absolute count of basophils in chicken blood were observed on Day 3, Day 5, Day 7 and Day 9 (by 45 %, 30 %, 67 % and 52 % respectively), while in duckling blood the absolute count of basophils decreased, once only, by 38% on Day 3.

Table 1.

Dynamics of monocytes, lymphocytes and eosinophils indices in chickens

Cells	Groups	Days				
		1	3	5	7	9
monocytes, %	1	3,8±0,48	3,3±0,56	1,5±0,22	1,7±0,33	2,5±0,22
	2	1,7±0,33**	2,8 ±0,31	2,3±0,33	3,3±0,33*	3,1±0,48
monocytes, $10^9 \cdot L^{-1}$	1	0,88±0,12	0,55±0,09	0,32±0,06	0,38±0,09	0,57±0,08
	2	0,32±0,06**	0,56±0,06	0,54±0,09	0,67±0,09*	0,69±0,14
lymphocytes, %	1	40,5±3,73	40,3±0,92	50,2±1,89	48,7±2,04	51,2±1,17
	2	41,7±2,36	44,0±2,05	45,8±2,06	38,8±2,24**	44,2±2,39
lymphocytes, $10^9 \cdot L^{-1}$	1	9,26±1,12	6,75±0,45	10,7±0,74	11,0±0,53	11,4±0,62
	2	7,99±0,55	0,73±0,41*	10,6±0,96	7,58±0,52**	9,52±1,02
eosinophils, %	1	10,1±1,15	17,0±2,44	7,0±0,68	8,5±0,76	9,8±1,25
	2	11,2±1,08	10,7±1,49	9,0±0,45*	12,2±0,95*	20,0±3,62*
eosinophils, $10^9 \cdot L^{-1}$	1	2,27±0,29	2,92±0,55	1,52±0,22	1,93±0,19	2,20±0,33
	2	2,13±0,18	2,13±0,33	2,09±0,19	2,43±0,31	4,18±0,72

**$p<0,01$ (Mann–Whitney U-test).

*$p<0,05$ (Mann–Whitney U-test).

We also registered a dynamic increase in relative count (percentage) of basophils in chicken blood in Group 2, there was no similar increase in duckling blood in the experimental group. It is probable that such an increase was caused by a certain allergic reaction, passing in chicken organism. That could be proven

by significant eosinophilia in Group 2 on Day 5 (22 %), Days 7 and 9 (over 50 %). The presence of high amounts of histamine in basophils is the evidence that basophils are as much involved in allergic reactions as eosinophils and there is functional interdependence between these 2 kinds of granulocytes, causing their counts to increase simultaneously.

Table 2.

Dynamics of pseudoeosinophils and basophils indices in chickens

Cells	Groups	Days				
		1	3	5	7	9
pseudoeosinophils, %	1	38,3±2,82	36,3±2,59	38,2±2,25	39,1±2,19	34,7±1,28
	2	37,2±2,61	38,0±1,81	36,7±1,94	38,7±2,17	28,7±2,32
pseudoeosinophils, $10^9 \cdot L^{-1}$	1	8,64±0,71	5,99±0,29	8,14±0,52	8,89±0,65	7,74±0,48
	2	7,18±0,71	7,69±0,75	8,34±0,27	7,61±0,66	6,08±0,51*
basophils, %	1	7,3±1,21	3,1±0,45	3,0±0,36	2,0±0,26	1,8±0,31
	2	8,2±0,71	4,5±0,43	6,2±0,61**	7,0±0,52**	4,0±0,36**
basophils, $10^9 \cdot L^{-1}$	1	1,65±0,26	1,65±0,26	0,64±0,08	0,45±0,06	0,41±0,07
	2	1,58±0,08	1,58±0,08	1,39±0,09**	1,38±0,16**	0,86±0,11**

**p<0,01 (Mann–Whitney U-test).
*p<0,05 (Mann–Whitney U-test).

Eosinophilia may also be a response of organism to certain drug components, acting as antigens. Evidently such reaction was observed in ducklings in experimental group and it explains the ambiguous undulating change of relative count (percentage) of eosinophils in duckling blood (Table 3, 4).

Table 3.

Dynamics of monocytes and lymphocytes indices in ducklings

Cells	Groups	Days				
		1	3	5	7	9
monocytes, %	3	2,0±0,36	1,3±0,21	1,0±0,00	1,5±0,34	1,1±0,17
	4	1,1±0,17	1,3±0,21	1,8±0,41	1,2±0,17	1,2±0,17
monocytes, $10^9 \cdot L^{-1}$	3	0,38±0,05	0,26±0,05	0,24±0,01	0,37±0,09	0,29±0,04
	4	0,21±0,03*	0,29±0,06	0,39±0,09	0,31±0,03	0,32±0,04
lymphocytes, %	3	33,5±3,77	42,3±2,31	33,7±3,07	53,8±6,44	29,8±1,94
	4	36,2±2,98	32,8±1,14**	37,3±0,88	29,0±3,04**	31,3±2,76
lymphocytes, $10^9 \cdot L^{-1}$	3	6,76±0,98	8,48±0,78	7,88±0,53	13,3±1,47	7,08±0,53
	4	6,75±0,43	6,77±0,29*	8,32 0,27	7,81±0,88**	8,37±0,79

**p<0,01 (Mann–Whitney U-test), *p<0,05 (Mann–Whitney U-test).

Transitory but more pronounced changes were observed in dynamics of pseudoeosinophils in Group 4 (Table 2), as compared to Group 2, where a reliable decrease (21%) was observed on Day 9 after withdrawal of Enrofloxacin. Increase in pseudoeosinophil count in duckling blood occurred on Day 3 and Day 7, 20% and over 50% respectively. The transitory reaction of pseudoeosinophils in duckling blood whereas such reaction was not registered in chicken blood can be explained by a faster physiological growth of the former as compared to the latter. As for short duration of the surge in count of these granulocytes it was probably determined by their protective function (mobilization of the immune system) against foreign substances, entering the organism [24, 25].

Table 4.

Dynamics of eosinophils, pseudoeosinophils and basophils indices in ducklings

Cells	Groups	Days				
		1	3	5	7	9
eosinophils, %	3	3,5±0,43	3,7±0,49	3,0±0,82	8,7±2,87	3,7±0,88
	4	5,2±0,71*	3,7±0,56	3,8±0,61	2,3±0,49*	6,3±0,67*
eosinophils, $10^9 \cdot L^{-1}$	3	0,68±0,08	0,74±0,13	0,71±0,19	2,15±0,76	0,89±0,23
	4	0,96±0,14	0,78±0,14	0,84±0,13	0,64±0,14*	1,69±0,17*
pseudoeosinophils,%	3	59,3±3,67	50,5±2,36	61,2±3,39	33,5±4,45	63,2±2,57
	4	56,0±3,09	61,0±1,24**	55,8±1,61	65,2±2,79**	60,0±2,74
pseudoeosinophils, $10^9 \cdot L^{-1}$	3	11,9±0,96	10,1±0,63	14,6±1,16	8,57±1,38	14,9±1,01
	4	10,8±1,11	12,6±0,53*	12,5±0,52	17,6±1,09**	16,0±1,01
basophils, %	3	1,5±0,34	2,2±0,17	1,1±0,17	2,5±0,34	2,2±0,61
	4	1,5±0,34	1,2±0,17**	1,3±0,17	2,3±0,56	1,2±0,17
basophils, $10^9 \cdot L^{-1}$	3	0,28±0,06	0,42±0,04	0,27±0,03	0,61±0,08	0,54±0,15
	4	0,28±0,08	0,26±0,05*	0,25±0,04	0,64±0,15	0,32±0,04

**p<0,01 (Mann–Whitney U-test).

*p<0,05 (Mann–Whitney U-test).

Dynamics of lymphocyte count in both chicken blood and duckling blood was ambiguous as we registered its alternate changes. Lymphocyte count in chicken blood increased reliably on Day 3 (by 22%), then decreased on Day 7 while dynamics of lymphocyte count in blood of ducklings in Group 4 was undulating. Lymphocyte count in duckling blood (Group 4) decreased reliably by 20% as compared to the control group on Day 3, then it increased by more than 50% on Day 5, but it decreased again by 41% on Day 7. Such dynamics may be related to fluoroquinolones' effect on production of interleukin-2 which in its turn promotes proliferation of such agranulocytes in organism.

Changes in monocyte count in the blood of all experimental groups were transitory. So monocyte count decreased by 63% in Group 2 on Day 1 after withdrawal of the drug, then it increased by 38% on Day 7. The change in monocyte count in duckling blood occurred only once and was observed on Day 1, when it decreased by 45% as compared to the control group.

Despite the fact that shift in the leukogram was more pronounced in Group 2 as compared to Group 3, we must note the dynamics of leukocyte indices in the duckling blood as well as these changes were more lasting and reliable. Leukocyte indices are very important for diagnosis as they enable us to evaluate the functioning of effector mechanisms of the immune system and the level of immunological reactivity. Moreover they can reflect possible elevated concentrations of toxic substances in the bloodstream.

In Group 2 (Table 5) reliable changes mostly occurred in IIR as compared to control (increase by 62% at Day 1, decrease by 14%, 36% and 60% at Day 3, Day 5 and Day 7 respectively), in LSI once at Day 7 (increase by 29%) and in LGI once at Day 7 too (decrease by 31%), though in Group 3 we marked dynamics in each of the studied indices (Table 6).

Table 5.

Dynamics of leukocyte indices in chicken blood

Index	Group	Day 1	Day 3	Day 5	Day 7	Day 9
LII	I	0,64±0,07	0,58±0,06	0,63±0,06	0,65±0,06	0,53±0,03
	II	0,60±0,06	0,62±0,05	0,59±0,05	0,64±0,06	0,41±0,05
LSI	I	1,34±0,19	1,29±0,05	0,95±0,07	1,00±0,08	0,87±0,04
	II	1,34±0,12	1,16±0,09	1,09±0,11	1,41±1,14**	1,14±0,11
LGI	I	0,78±0,15	0,72±0,03	1,05±0,08	0,99±0,08	1,11±0,05
	II	0,75±0,08	0,84±0,08	0,89±0,07	0,68±0,06**	0,86±0,09
KI	I	1,01±0,15	0,91±0,08	0,78±0,07	0,82±0,08	0,68±0,04
	II	0,92±0,11	0,88±0,07	0,82±0,09	1,03±0,14	0,65±0,06
LI	I	1,13±0,21	1,14±0,09	1,35±0,14	1,27±0,12	1,49±0,08
	II	1,17±0,15	1,18±0,11	1,28±0,11	1,03±0,11	1,58±0,13
IIR	I	14,3±1,93	23,8±8,91	42,9±6,66	41,2±7,22	25,5±2,49
	II	38,6±7,56**	20,5±2,46	27,6±6,57*	16,5±2,55**	22,3±2,78

**p<0,01 (Mann–Whitney U-test).

*p<0,05 (Mann–Whitney U-test).

Besides, the registered changes in duckling blood were particularly pronounced at Day 3 and Day 7. In accordance with it KI, LII, LSI increased on the same days by 34% and 68%, 34% and 72%, 31% and 59% respectively, while

LI and LGI decreased reliably by 54% and 76%, 35% and 70%, respectively. We also observed a singular increase of IIR by 40% at Day 1.

Table 6.

Dynamics of leukocyte indices in duckling blood

Index	Group	Day 1	Day 3	Day 5	Day 7	Day 9
LII	III	1,56±0,19	1,04±0,09	1,66±0,21	0,54±0,11	1,78±0,19
	IV	1,33±0,16	1,58±0,08*	1,27±0,08	1,96±0,23**	1,56±0,18
LSI	III	1,95±0,25	1,33±0,13	1,98±0,22	1,01±0,35	2,29±0,21
	IV	1,77±0,22	1,94±0,08**	1,57±0,08	2,48±0,34**	2,21±0,31
LGI	III	0,55±0,11	0,77±0,08	0,53±0,08	1,43±0,32	0,44±0,04
	IV	0,59±0,08	0,50±0,02**	0,62±0,03	0,43±0,07**	0,48±0,06
KI	III	1,92±0,26	1,23±0,12	1,92±0,23	0,76±0,24	2,19±0,22
	IV	1,64±0,21	1,87±0,09**	1,50±0,07	2,41±0,32**	2,04±0,29
LI	III	0,60±0,12	0,86±0,09	0,58±0,09	1,92±0,48	0,48±0,05
	IV	0,67±0,09	0,54±0,03**	0,67±0,03	0,46±0,07**	0,54±0,07
IIR	III	22,2±4,41	37,7±4,37	36,7±3,24	49,8±8,41	29,8±2,31
	IV	37,2±3,84*	30,7±4,26	27,9±5,08	28,3±0,15	34,6±4,15

**p<0,01 (Mann–Whitney U-test).
*p<0,05 (Mann–Whitney U-test).

The differences in dynamics of hematological parameters are remarkable in that we see bigger changes of leukogram values in chicken blood while in duckling blood we see more pronounced changes of leukocyte (hematological) indices; such differences may be related to peculiar susceptibility of leukocyte subpopulations of different kinds of poultry to the studied drug.

There are a few reports of hematological studies in mammals revealing certain side effects after fluoroquinolone administration, nevertheless such effects are quite rare and such cases are seldom reported. Bearing a possibility of such effects in mind we studied blood indices of 2 kinds of poultry and did not register any adverse events in their blood or consequences after fluoroquinolone administration. Those transitory changes that we marked may be to a great degree related to peculiarities and individual development of ducklings and chickens at such young age.

Conclusion

The data that we obtained after conducting 2 series of experiments do not show any significant negative effect of Enrofloxacin administration on physiological state of poultry. But the fact remains that dynamics of hematological

indices was more pronounced in the experimental group of chickens as compared to ducklings, which could be related to specific, peculiar development of the latter. Nevertheless the changes that we observed in blood indices of both experimental groups were not lasting and as a rule the blood indices did not show any significant reliable changes till the final day of the experiments.

Acknowledgements. The article is recommended for publication by the Organizing Committee of the IV International Symposium «Innovations in Life Sciences», 2022, Belgorod, Russia.

Conflict of interest. There is no conflict of interest stated by authors.

References / Список литературы

1. Bhanot S.K., Singh M., Chatterjee N.R. The chemical and biological aspects of fluoroquinolones: reality and dreams // Current pharmaceutical design. 2001. Vol. 7(5). P. 311-335. https://doi.org/10.2174/1381612013398059
2. Tazi A., Gueudet T., Varon, Gilly L., Trieu-Cuot P., Poyart C. Fluoroquinolone-resistant group B streptococci in acute exacerbation of chronic bronchitis // Emerging infectious diseases. 2008. Vol. 14(2). P. 349-350. https://doi.org/10.3201/eid1402.071006
3. Neemuchwala A., Teatero S., Patel S., Fittipaldi N. Fluoroquinolone resistance among clonal complex 1 group B Streptococcus strains // Canadian Journal of Infectious Diseases and Medical Microbiology. 2016. Vol. 31. URL: https://www.hindawi.com/journals/cjidmm/2016/6403928/
4. Rodriguez-Martinez J.M., Cano M.E., Velasco C.A. Plasmid-mediated quinolone resistance: un update // Journal of Infection and Chemotherapy. 2017. Vol. 17(2). P. 149-182. https://doi.org/10.1007/s10156-010-0120-2
5. Ramatla T., Ngoma L., Adetunji M., Mwanza M. Evolution of antibiotic residues in raw meat using different analytical methods // Antibiotics. 2017. Vol. 6(4). P. 34. https://doi.org/10.3390/antibiotics6040034
6. Chantziaras I., Smet A., Fillipitzi M. The effect of a commercial competitive exclusion product on the selection of ciprofloxacin resistance in commercial *E. coli* in broilers // Avian Pathology. 2018. Vol. 47(5). P. 443-454. https://doi.org/10.1080/03079457.2018.1486027
7. Andersson M.I., MacGowan A.P. Development of the quinolones // Journal of Antimicrobial Chemotherapy. 2003. Vol. 51(1). P. 1-11. https://doi.org/10.1093/jac/dkg212
8. Moiseeva A.A., Prisnyi A.A., Gulyukin A.M., Stepanova T.V. Leukocytes differential under effect of ciprofloxacin in experimental colibacillosis in chick-

ens // IOP Conference Series: Earth and Enviromental Science. 2020. Vol. 548. https://doi.org/10.1088/1755-1315/548/4/042044
9. Prisnyi A.A., Moiseeva A.A., Skvortsov V.N. Effect of ciprofloxacin on chicken blood parameters after an experimental infections // IOP Conference Series: Earth and Enviromental Science. 2020, Vol. 421. https://doi.org/10.1088/1755-1315/421/5/052027
10. Goudah A., Hasabelnaby S. Dispositin kinetics of levofloxacin in sheep after intravenous and intramuscular administration // Veterinary Medicine International. 2010. 727231. 2 Nov. 2010. https://doi.org/10.4061/2010/727231
11. Salih Y.Z. Toxic effect of ciprofloxacin on some biochemical variables in chickens // Journal of Veterinary Science. 2010. Vol. 24(2). P. 137-141. https://doi.org/10.33899/ijvs.2010.5603
12. Yassin H., Velthuis A.G., Boerjan M., van Riel J. Field study on broilers first-week mortality // Poultry Science. 2009. Vol. 88(2). P. 798-804. https://doi.org/10.3382/ps.2008-00292
13. Olsen R., Frantzen C., Christensen H., Bisgaard M. An investigation on first-week mortality in lagers // Avian Diseases. 2012. Vol. 56. P. 51-57. https://doi.org/10.1637/9777-051011-Reg.1
14. Kemmett K., Williams N.J., Chaloner G., Humphrey S., Wigley P., Humphrey T. The contribution of systemic *Escherichia coli* infection to the early mortalities of commercial broiler chickens // Avian Pathologic. 2014. Vol. 43(1). P. 37-42. https://doi.org/10.1080/03079457.2013.866213
15. Ruby T., McLaughlin L., Gopinath S., Monack D. Salmonella long-test relationship with its host // FEMS Microbiology Reviews. 2012. Vol. 36(3). P. 600-615. https://doi.org/10.1111/j.1574-6976.2012.00332.x
16. Haag G., Marin G.H., Errecalde J. Quantification of residual enrofloxacin and ciprofloxacin in feathers of broiler chickens by high-perfomance liquid chromatography – fluorescence after oral administration of the drugs // Journal of Advanced Pharmaceutical Technology. 2016. Vol. 7(1). P. 2-5. https://doi.org/10.4103/2231-4040.173265
17. Reyes-Herrera I., Schneider M.J., Blore P.J., Donoghue D.J. The relationship between and muscle samples to monitor for residues of the antibiotic enrofloxacin in chickens // Poultry Science. 2011. Vol. 90(2). P. 481-485. https://doi.org/10.3382/ps.2010-01057
18. Devreese M., Antonissen G., De Baere S., De Backer P., Croubels S. Effect of administration route and dose escalation on plasma and intestinal concentrations of enrofloxacin and ciprofloxacin in broiler chickens // BMC Veterinary Research. 2014. Vol. 10. P. 289-291. https://doi.org/10.1186/s12917-014-0289-1

19. Trouchon T., Lefebvre S. A review of enrofloxacin in pore liver and chicken // Journal of Veterinary Medicines. 2016. Vol. 6. P. 40-58. https://doi.org/10.4236/ojvm.2016.62006
20. Govendir M., Hansen T., Kimble B., Norris J.M., Baral R.M., Wigney D.I., Gottlieb S. Malik R. Susceptibility of rapidly growing mycobacteria isolated from cats and dogs, to ciprofloxacin, enrofloxacin and moxifloxacin // Veterinary Microbiology. 2011. Vol. 147(1-2). P. 113-118. https://doi.org/10.1016/j.vetmic.2010.06.011
21. Khan A.T., Zafar F. Hematological study in response of varying doses of estrogen in broiler chicken // International Journal of Poultry Science. 2005. Vol. 4(10). P. 748-751. https://doi.org/10.3923/ijps.2005.748.751
22. Togun A.V., Oseni B.S. Effect of low level inclusion biscuit dust in broiler finished diet on pre-pubertal growth and some hematological parameters of unsexed broilers // Journal of Animal Science. 2005. Vol. 1. P. 10-14.
23. Gurbay A., Gonthier B., Daveloose D., Favier A., Hincal F. Microsomal metabolism of ciprofloxacin generates free radicals // Free Radical Biology and Medicine. 2001. Vol. 30. P. 1118-1121. https://doi.org/10.1016/s0891-5849(01)00508-1
24. Ahmad Z., Xie M., Wu Y., Hou S. Effect of Supplemental Cyanocobalamin on the Growth Performance and Hematological Indicators of the White Pekin Ducks from Hatch to Day 21 // Animals. 2019. Vol. 9(9). P. 633. https://doi.org/10.3390/ani9090633
25. Kroliczewska B., Graczyk S., Kroliczewski J. Investigation of the immune effects of *Scutellaria bacalensis* on blood leycocytes selected organs of the chickens lymphatic system // Journal of Animal Science and Biotechnological. 2017. Vol. 8(22). P. 1-12. https://doi.org/10.1186/s40104-017-0152-x

DATA ABOUT THE AUTHORS

Anna A. Moiseeva, Researcher

Federal Research Center – All-Russian Research Institute of Experimental Veterinary Medicine named after K.I. Scriabin and Ya.R. Kovalenko of the Russian Academy of Sciences, Belgorod Department
4th, Kurskaya Str., Belgorod, 308002, Russian Federation
annamoiseeva1202@yandex.ru
SPIN-code: 2515-3804
ORCID: https://orcid.org/0000-0003-2730-3012
ResearcherID: AAH-1579-2019
Scopus Author ID: 57214232539

Andrey A. Prisnyi, Doctor of Biology, Associated professor, Institute of Pharmacy, Chemistry and Biology, Director
Federal State Autonomous Educational Institution of Higher Education «Belgorod National Research University»
85th, Pobedy Str., Belgorod, 308015, Russian Federation
andreyprisny@gmail.com
SPIN-code: 2523-4576
ORCID: https://orcid.org/0000-0001-5229-8337
ResearcherID: M-9243-2017
Scopus Author ID: 56358999400

Vladimir N. Skvortsov, Doctor of Veterinary, Head of Belgorod Department
Federal Research Center – All-Russian Research Institute of Experimental Veterinary Medicine named after K.I. Scriabin and Ya.R. Kovalenko of the Russian Academy of Sciences, Belgorod Department
4th, Kurskaya Str., Belgorod, 308002, Russian Federation
skvn59@yandex.ru
SPIN-code: 2006-3989
ORCID: https://orcid.org/0000-0002-9629-0000
ResearcherID: AAN-4978-2020
Scopus Author ID: 57193017500

ДАННЫЕ ОБ АВТОРАХ

Моисеева Анна Анатольевна, научный сотрудник
ФГБНУ «Федеральный научный центр – Всероссийский научно-исследовательский институт экспериментальной ветеринарии имени К.И. Скрябина и Я.Р. Коваленко Российской академии наук», Белгородский филиал
ул. Курская, 4, г. Белгород, 308002, Российская Федерация
annamoiseeva1202@yandex.ru

Присный Андрей Андреевич, доктор биологических наук, доцент, директор Института фармации, химии и биологии
ФГАОУ ВО «Белгородский государственный национальный исследовательский университет»
ул. Победы, 85, г. Белгород, 308015, Российская Федерация
andreyprisny@gmail.com

Скворцов Владимир Николаевич, доктор ветеринарных наук, руководитель Белгородского филиала
ФГБНУ «Федеральный научный центр – Всероссийский научно-исследовательский институт экспериментальной ветеринарии имени К.И. Скрябина и Я.Р. Коваленко Российской академии наук», Белгородский филиал
ул. Курская, 4, г. Белгород, 308002, Российская Федерация
skvn59@yandex.ru

Поступила 10.05.2022
После рецензирования 31.05.2022
Принята 10.06.2022

Received 10.05.2022
Revised 31.05.2022
Accepted 10.06.2022