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MAŁGORZATA TARGOŃSKA-KARASEK¹, ŁUKASZ WLAZŁO²

HENRYK KRUKOWSKI³, WOJCIECH OSPALEK⁴

Resistance of *Pseudomonas aeruginosa* strains to Rivanol

Abstract. The aim of the study was to determine the sensitivity of two strains of *Pseudomonas aeruginosa* to Rivanol 0.1% (ethacridine). The tests were carried out using the macrodilution method in Brain Heart Infusion (BHI) broth in the concentration range from 1 : 512 to 1 : 1, using an inoculum with a density of 0.5 McFarland. The values of the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) were assessed. It was found that both strains showed bacterial growth in most of the tested concentrations, and complete inhibition of bacterial growth and bactericidal effect were noted only at the highest concentration used (1 : 1). These results indicate a high resistance of the tested *P. aeruginosa* strains to Rivanol, which may limit its use in the therapy of infections caused by this species. Further research on more effective antibacterial compounds and strategies supporting the therapy of infections caused by multidrug-resistant strains seems to be necessary.

Keywords: *Pseudomonas aeruginosa*, Rivanol, ethacridine, MIC, MBC, resistance

INTRODUCTION

Pseudomonas aeruginosa is an opportunistic Gram-negative pathogen of great importance in human and veterinary medicine. It is the cause of numerous hospital infections, especially in patients with reduced immunity, after surgery, during artificial ventilation or with burns [Pang et al. 2019, Qin et al. 2022]. A particular difficulty in treating infections caused by this species is its natural and acquired resistance to a wide range of antibiotics and disinfectants [Namaki et al. 2022, Akiola Sanya et al. 2023]. The resistance of *P. aeruginosa* is due to, among other things, the presence of numerous efflux pumps (MexAB-OprM, MexXY and other systems), low permeability of the outer membrane and the ability to form biofilms, which increase drug tolerance many times over [Egorova et al. 2022]. For this reason, this bacterium has been classified by the WHO as one of the critical priority pathogens, requiring the urgent development of new therapeutic strategies [WHO 2017].

Rivanol (ethacridine) is an acridine dye with antiseptic action, used in the treatment of superficial wounds and ulcers. Its mode of action involves intercalation into the DNA molecule, disruption of its replication and inhibition of nucleic acid synthesis [Jabri et al. 2023]. Despite many years of using in dermatology and surgery, limited effectiveness of Rivanol against Gram-negative bacteria, including *P. aeruginosa* [Namaki et al. 2022], is increasingly observed.

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The aim of this study was to determine the value of the minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) of Rivanol for two strains of *P. aeruginosa* stored in the resources of the Department of Animal Hygiene and Environmental Hazards of the University of Life Sciences in Lublin.

MATERIAL AND METHODS

Bacterial strains

Two clinical isolates of *Pseudomonas aeruginosa* designated as PA-LUB1 and PA-LUB2 used in this study were identical to those previously described in a published study [Targońska-Karasek et al. 2025], which provided their detailed microbiological characterization.

Preparation of inoculum

Bacterial suspensions were prepared in sterile physiological saline (0.85%) and adjusted to a turbidity of 0.5 McFarland standard. A volume of 0.5 ml of this suspension was transferred into a sterile tube containing 4.5 ml of brain heart infusion (BHI) broth and homogenized to ensure uniform distribution.

Determination of MIC and MBC

Rivanol used in the study was a 0.1% solution, with 1 mg of ethacridine lactate in each gram of liquid. MIC and MBC of Rivanol against *P. aeruginosa* were determined by a twofold serial macrodilution technique, adapted from Melville et al. [2003]. Eleven sterile glass test tubes were prepared, each initially containing 5 ml of sterile BHI broth. Into the first tube, 5 ml of undiluted Rivanol solution was added and mixed thoroughly. Subsequently, 5 ml from this tube was transferred into the second tube and mixed, then 5 ml from the second tube was transferred into the third, and so on, through to the eleventh tube. This procedure produced a series of twofold dilutions. An additional tube containing undiluted Rivanol (1 : 0) was also prepared. Each tube was inoculated with 0.5 ml of bacterial suspension. All tubes were incubated at 37°C for 24 hours. MIC was determined as the lowest concentration showing no turbidity. Additionally, all samples were subcultured on Mueller-Hinton agar to determine MBC. All experiments were performed in two independent biological replicates, each in technical duplicate, to ensure reproducibility.

Results were analyzed descriptively due to the qualitative nature of the MIC/MBC data (growth/no growth). Mean values from replicates were used to confirm consistency of results. Data reproducibility between replicates was assessed by comparing the obtained MIC and MBC values for both strains

RESULTS

The results of MIC and MBC determinations are presented in Table 1. Both *P. aeruginosa* strains showed consistent results across all replicates grew over a wide range of Rivanol concentrations from 1 : 512 to 1 : 2. Both the MIC and MBC for the PA-LUB1 and PA-LUB2 strains were only 1 : 1, which indicates a high tolerance of the tested isolates to ethacridine. No differences between replicates were recorded.

Table 1. MIC and MBC of Rivanol – against *P. aeruginosa* strains

Strain	MIC	MBC
PA-LUB1	1 : 1	1 : 1
PA-LUB2	1 : 1	1 : 1

DISCUSSION

The results of this study confirm the high resistance of *P. aeruginosa* to Rivanol, which is consistent with reports of limited effectiveness of acridine dyes against Gram-negative rods [Namaki et al. 2022]. The main mechanisms of this resistance include the presence of MexAB-OprM efflux pumps and reduced permeability of the outer membrane to hydrophobic compounds [Pang et al. 2019, Egorova et al. 2022]. Additionally, the ability of *P. aeruginosa* to form biofilms may significantly limit the penetration of antiseptics and antibiotics into bacterial structures [Egorova et al. 2022].

It should be emphasized that Rivanol in clinical practice is mainly used to treat superficial skin and wound infections. Its use in deep or systemic infections is limited. The obtained MIC and MBC values of 1 : 1 for *P. aeruginosa* strains suggest the need to use practically undiluted concentrations, which is difficult to achieve in conditions that are safe for the patient's tissues. Similar observations have also been shown for other biocides, including octenidine and chlorhexidine, which in the case of multidrug-resistant *P. aeruginosa* strains often require much higher concentrations than those declared by the manufacturers to achieve a bactericidal effect [Namaki et al. 2022].

Modern approaches to combating infections caused by *P. aeruginosa* include the use of efflux pump inhibitors (e.g. phenylalanine-arginine β -naphthylamide) and metal nanoparticles (TiO_2 , Ag), which can increase membrane permeability and the effectiveness of existing disinfectants [Qais et al. 2023, Akiola Sanya et al. 2023]. Other strategies include enzymes that break down the biofilm matrix or signaling compounds that inhibit quorum sensing, reducing the expression of virulence factors [Qin et al. 2022].

CONCLUSIONS

The *P. aeruginosa* strains studied were highly resistant to Rivanol, as evidenced by MIC and MBC values at the level of 1 : 1.

These results indicate the limited usefulness of ethacridine in the treatment of infections caused by multidrug-resistant *P. aeruginosa* strains.

Further research is needed on alternative therapeutic strategies, including new antiseptics, efflux pump inhibitors, and methods of disrupting biofilms.

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Ethical statement: No additional ethical approval was required for this study, as the biological sample was collected during routine veterinary medical care while the companion animal was under anaesthesia, with no additional procedures performed beyond standard clinical practice.

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The effect of various methods of additional feed application during the first days of rearing on broiler chickens performance

Abstract. The aim of the study was to determine the impact of various methods of feed administration during the early days of meat-type chickens rearing on their livability and final performance under typical farm conditions. Day-old Ross 308 chicks were allocated to three experimental groups. During the first week of rearing, in group A (the control one) the feed mixture was administered only *via* automatic feeding line (2 cm of feeder edge length per chick). In groups B and C birds were provided with additional access to feed on the litter covered with grey corrugated paper or commercial chick paper (covered with wax layer), respectively. The birds were kept in pens of equal stock density, the area of paper constituted 30% of each pen area. Mortality cases and body weight of birds were registered. After 42 days birds were commercially slaughtered and 20 carcasses from each group were randomly chosen and subjected to simplified dissection. Feed administration on paper strips considerably improved liveability of birds during the first week of life. Mortality in group A mainly resulted from the fact that chicks did not begin ingesting the feed. The additional feeding of birds using cardboard or paper strips on the litter had positive effects on their gastrointestinal tract development and some production results. The grey corrugated cardboard seemed to be more effective in this respect.

Key words: newly-hatched chicks, early feeding, feeding methods, corrugated paper, chick paper

INTRODUCTION

The first week of rearing broiler chickens is crucial for their further development as well as for the achieved production effects [Yerpes et al. 2020]. Lilburn [1998] stated that it affects approximately 17% of body weight. The breeder's priority is to provide chicks with feed and water as soon as possible. Noy et al. [1996] demonstrated that yolk sac absorption is markedly more intensive in early-fed chicks than in birds whose access to the first feed is delayed. It is accelerated as a result of intestinal activity stimulation. Early feed ingest is also conducive to digestive tract development [Cengiz et al. 2012, Qu et al. 2021], which in turn enhances its ability to digest and assimilate feed nutrients and further contributes to birds' productivity [Yang et al. 2008]. The first feed ingest also positively modulates the function of the birds' immune system, among other things, by enhancing disease resistance [Wijnen et al. 2021] and contributing to maximizing their survivability [Dibner et al. 1998, Yassin et al. 2009].

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The term “early feeding” of chicks can be considered in many aspects. In terms of the type and quality of the feed [Toghyani et al. 2012], the time of feed application [Noy and Sklan 1999] and, finally, its accessibility for chicks. Boyner et al. [2021] observed that chicks remain inactive for a considerable amount of time before initiating foraging. Eating activity, defined as birds eating or standing close to the feeder, was observed in 5% (5/100 birds) at an average biological age of 25.4 h, while 50% of birds had full crops at an average age of 30.6 h. Therefore, the use of additional feed sources (paper or cardboard strips, egg cartons, etc.) can, firstly, enrich the environment, stimulating the chicks’ curiosity, and secondly, ensure rapid feed intake through natural foraging before the birds learn to use conventional feeders.

Only limited scientific literature addresses methods of feed application for 1-day-old chickens, with most studies focusing on the effects of delayed first feeding [Proszkowiec-Weglarz et al. 2020, 2022, El-Azeem et al. 2024], rather than the method of feeding itself. Currently, some farmers are encouraged to use commercially available chick paper. It is marketed as an indispensable product that increases foraging activity, absorbs droppings and thereby improves house hygiene, is biodegradable, and equalizes the chicks’ access to feeders. The use of such paper is expected to improve the survivability and productivity of birds. However, there is currently no scientific evidence confirming these advantages and justifying the additional cost.

The aim of this study was to determine the effect of various feeding methods during the first week of broiler chicken rearing on their survivability and selected final production parameters.

MATERIALS AND METHODS

The experiment was carried out under farm conditions on meat-type chickens during the standard production cycle.

As the birds were kept as a commercial flock and slaughtered at the end of a typical, commercial production cycle, no experimental procedures compromising animal welfare were performed during rearing. According to the legislation in force (Act of 15 January 2015 on the protection of animals used for scientific or educational purposes; Directive 2010/63/EU of the European Parliament and of the Council of 22 September 2010 on the protection of animals used for scientific purposes), ethics committee approval was not required for the study.

Broiler chickens were kept on the experimental farm under the housing conditions indicated in Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. Microclimatic conditions and lighting were kept according to the recommendations of the manufacturer of the Ross 308 commercial hybrids (Aviagen®).

The 1-day-old unsexed Ross 308 chickens were allocated to three experimental groups. Control group (A) consisted of 6500 chickens, while experimental groups B and C comprised 3250 birds each. Throughout the fattening period, all groups were kept in the same henhouse, in pens separated by mobile fences (approx. 1 m high). Each group sector was divided into 5 replication subgroups. Chickens were fed with standard balanced mixtures according to their age and requirements. The birds were provided with *ad libitum* access to balanced feed and water. The composition and nutritive value of feed mixtures, based on the manufacturer’s declaration, is shown in tables 1 and 2.

The groups of chickens were differentiated according to the additional source of feed. The control group (A) was fed traditionally using only automatic feeders, providing approximately 2 cm of the feeder edge length per bird. The experimental groups were provided with additional access to the feed placed on chick paper stripes on the litter. In group B the litter was covered with grey corrugated cardboard ($0.65 \text{ m}^2/10 \text{ m}^2$), whereas in group C, the paper was smooth, green and unilaterally coated with wax ($0.65 \text{ m}^2/10 \text{ m}^2$). In both experimental groups, the paper-covered area accounted for 30% of total area available to the birds. Paper stripes were placed along the feeding lines, 30 cm from the watering line. Groups B and C were given 500 kg (100 kg per replication subgroup) of prestarter feed in the crumble form, spread uniformly on paper each day during the first rearing week. The same amount of feed was also received by control group A.

Table 1. The composition of feed mixtures used during the experiment

Ingredients (%)	Prestarter	Starter	Grower 1	Grower 2	Finisher
Wheat 11%	60.00	60.22	60.39	62.01	64.47
Rapeseed meal	1.50	3.00	3.00	5.00	7.00
Soybean meal 46%	30.00	28.50	28.25	24.70	20.44
Fish meal	0.50	0.50	0.01	0.01	0.01
Soybean oil	3.50	4.33	5.38	5.82	5.89
Calcium phosphate	1.50	0.64	0.49	0.28	0.35
Limestone	1.50	1.51	1.18	0.89	0.82
NaCl	0.50	0.30	0.27	0.25	
Rapeseed oil			0.01	0.01	
Premix	1.00	1.00	1.00	1.00	1.00
Lard			0.01	0.01	0.01
Rape-cake			0.01	0.01	
Blood meal				0.01	0.01
Total	100.00	100.00	100.00	100.00	100.00

Table 2. Nutritive value of feed mixtures used during the experiment

Item	Prestarter	Starter	Grower 1	Grower 2	Finisher
Total protein (%)	22.30	21.37	21.13	20.37	19.31
Metabolic energy (kcal)	2860	2825	2900	2950	2975
Ether extract (%)	6.882	6.508	7.561	8.004	8.064
Crude ash (%)	5.727	5.791	5.441	4.874	4.585
Crude fiber (%)	3.302	2.728	2.711	2.844	2.971
Lysine (%)	1.326	1.224	1.186	1.130	1.035
Methionine (%)	0.586	0.541	0.510	0.503	0.464
Methionine + cysteine (%)	0.962	0.897	0.863	0.854	0.809
Ca (%)	0.902	0.881	0.789	0.650	0.589
P (%)	0.617	0.549	0.512	0.468	0.485
Na (%)	0.150	0.150	0.138	0.130	0.133
NaCl (%)	0.424	0.453	0.409	0.391	0.410
Vitamin A (IU)	12563	12500	10000	10000	2000
Vitamin D ₃ (IU)	3518	3500	2500	2500	2000
Vitamin E (mg)	75.38	75.00	25.00	25.00	20.00

At the beginning of the experiment, 50 birds were randomly chosen from each replication group and marked with wing marks. They were used for body weight recording at 7-day intervals. Mortality and culling were also recorded. In the first week, the causes of death were determined by post-mortem examination.

The production cycle was completed on the 42nd day of the birds' lives. The chickens were slaughtered in commercial poultry slaughterhouse by decapitation (EU Regulation No. 1099/2009 of 24 Sep-

tember 2009 on the protection of animals at the time of killing), then plucked and eviscerated. The carcasses were then chilled to an internal temperature of 4 °C inside. 20 carcasses from each group were randomly chosen and subjected to simplified dissection [Hahn and Spindler 2002]. Carcass yield and the proportions of its elements were determined.

The data were analysed using the SPSS 24.0 software package [IBM 2017]. The normality of the data was assessed using the Shapiro-Wilk test. One-way analysis of variance with Tukey's post-hoc test was carried out. Non-parametric data were analysed using the χ^2 (Chi square) and/or Kruskal-Wallis test with pairwise comparisons. Differences were considered significant at $p \leq 0.05$ or $p \leq 0.01$.

RESULTS

Table 3 shows the number and causes of chicks losses during the first week of rearing. The highest mortality was observed in the control group (A), primarily due to starvation caused by the chicks' failure to ingest feed. In this group, 103 dead chicks were found, which accounted for 0.79% of the total number of chicks and 35.3% of chicks that died during the first week. In the experimental groups (B and C), mortality due to failure to initiate foraging was significantly lower and amounted to 21 and 20 chicks respectively, which together accounted for 0.32% of the total stock and 14.04% of the total number of dead birds during the first seven days of rearing. The proportions of birds that died due to failure to initiate feed ingest and post-hatched infection in the experimental groups (B and C) were the reverse of those in the control group (A). The number of deaths caused by infection remained at a similar level in all groups relative to their size. Out of 292 dead chicks from all three groups, only 13 chicks were culled. The number of deaths in the first week of rearing constituted 48% of the total number during entire production cycle, and almost 60% of dead chickens were found in the control group (A).

Table 3. The number and causes of chicks' mortality during the first week of rearing

Cause of dead	Group			χ^2 (<i>p</i> -value)
	A	B	C	
Chick which did not ingest feed	103 (58.8%)	21 (34.4%)	20 (35.7%)	<0.001
Yolk sac or hatchery infection	66 (37.7%)	37 (60.7%)	32 (57.1%)	<0.001
Culled and others	6 (3.4%)	3 (4.9%)	4 (7.1%)	<0.001
Total	175	61	56	<0.001

The number of birds that died in experimental groups during the particular weeks of rearing is shown in Table 4. The highest mortality rate was recorded in the first week of the experiment, which could have resulted from improper incubation conditions or post-hatch selection procedures. The number of deaths in groups B and C was more than 33% lower than in group A. In the second week, the value of this indicator in experimental groups exceeded the number of deaths found in the group fed only by automatic feeders by 28%. A decrease in mortality (by 36%) was observed in the group reared on green paper compared to the group reared on grey paper. At third week of rearing, mortality was equal in all groups, and in the subsequent weeks more birds died in the experimental groups (B and C) than in the control one (A), however, no infectious causes were identified. Finally, the proportion of mortality was similar across all groups; however, the total number of deaths in the experimental groups was higher than in the control group. Moreover, considerably more birds died during the final stage of the fattening period, which negatively affected the economic results. In group A, the highest number of deaths was recorded at the beginning of the rearing period, when production costs were relatively low, while in the last week only isolated mortality cases occurred, accounting for 0.09%.

The average body weight of birds at the end of consecutive rearing weeks is shown in table 5. The body weight at the day of hatching was equal in all groups and ranged from 41 to 42 g. After applying varied methods of feed application (in the 1st week of rearing) chickens from the control group (A) were heavier by 7.6 g (4.8%) and 5.2 g (over 2%) than the group kept on grey and green paper, respectively. On 14th and 21st day, the relationship was reversed and both experimental groups grew faster than the control group. The differences amounted to 6.1 and 7.4%, respectively, in favour of groups B and C, and they were statistically significant. From 28th day of fattening the body weight of birds was similar regardless of group. Finally, at the end of rearing period, the value of this trait ranged from 2442.3 to 2501.9 g and the differences were not statistically confirmed.

Table 4. Mortality of chicks in consecutive weeks of the experiment

Time (wks)	Group						Mortality (%)	χ^2 (<i>p</i> -value)
	A		B		C			
	No.	%	No.	%	No.	%		
1	175	60.76	61	38.13	56	35.22	2.25	<0.001
2	46	15.97	36	22.50	23	14.47	0.81	<0.001
3	32	11.11	31	19.38	42	26.42	0.81	<0.001
4	21	7.29	9	5.63	12	7.55	0.32	<0.001
5	8	2.78	13	8.13	14	8.81	0.27	<0.001
6	6	2.08	10	6.25	12	7.55	0.22	<0.001
Total	288	4.43	160	4.92	159	4.89	4.67	0.468

Table 5. The body weight of birds in consecutive weeks of experiment

Time (days)	Group						<i>p</i> -value
	A		B		C		
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
0	42.1	0.37	41.8	0.53	41.7	0.52	0.970
7	177.4 ^a	1.07	169.8 ^b	1.77	172.2 ^b	0.93	0.003
14	397.0 ^a	8.37	411.0 ^{ab}	19.49	417.0 ^b	11.51	0.038
21	751.1 ^a	28.39	800.0 ^b	27.30	811.1 ^b	30.79	<0.001
28	1299.0	97.80	1283.0	58.89	1242.0	73.91	0.197
35	1892.3	134.29	1900.0	76.21	1877.9	65.18	0.825
42	2501.9	103.56	2457.7	96.76	2442.3	95.13	0.236

^{a,b} – values in rows marked with different letters differ at $p \leq 0.05$

Table 6 presents the results of simplified dissection analysis of chickens according to experimental groups. The highest carcass yield was found in birds from group B. However, this value was only 0.2% higher than that obtained in the control group (A) and 2.46% higher than in group C. The proportion of breast muscles in carcasses of birds from the control group was similar to that of group B and considerably higher than in the experimental group C. In the experimental group maintained on green paper (C), a significantly larger proportion of trunk was recorded (19.26%), whereas a considerably larger proportion of wings was found in the carcasses of birds from group B. No differences were observed in the proportion of legs between groups. The impact of the additional feed source (grey corrugated cardboard/green waxed paper strips) for chickens on the proportion of edible giblets in their body weight was also confirmed. A significantly larger proportion of gizzard in body weight was observed in group B. Similar numerical relationships between groups were also found for the proportions of liver and heart.

Table 6. Results of simplified dissection in particular groups

Parameter		Group						p-value
		A		B		C		
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Carcass yield (%)		73.68 ^b	0.970	73.83 ^b	1.340	72.01 ^a	0.775	<0.001
Carass parts (%)	breast muscle	29.59 ^b	1.487	29.08 ^{ab}	1.630	27.72 ^a	1.690	0.001
	legs	41.06	1.531	41.34	1.452	41.87	1.445	0.477
	wings	11.07 ^a	0.675	11.46 ^b	0.426	11.23 ^{ab}	0.399	0.042
	trunk	18.28 ^{ab}	1.207	18.11 ^a	0.823	19.26 ^b	0.856	<0.001
Giblets (% bw)	gizzard	1.095 ^a	0.122	1.213 ^b	0.146	1.112 ^{ab}	0.134	0.014
	liver	1.951	0.308	2.046	0.230	2.043	0.193	0.372
	heart	0.451	0.047	0.469	0.052	0.439	0.052	0.191

^{a,b} – values in rows marked with different letters differ at $p \leq 0.05$; bw – body weight

DISCUSSION

Based on our results it seems that the use of paper in groups B and C played a role in increasing the accessibility of feed for chicks, as well as shortening the time to first feed ingest. However, the available literature in the field of alternative methods of feed application during the first week of broiler production is still limited. Ross 308 broilers are one of the most popular hybrids in the world and are often used as research material, including in nutritional studies. Comparing the results obtained in this study to others [Hristakieva et al. 2014, Al-Shammari et al. 2019, Ahmadzadeh et al. 2025], it should be noted that they are consistent with previous reports, regardless of the group.

Most authors focus on the consequences of delayed access to feed in newly hatched chicks. Pisarski et al. [1998] showed that a 24-hour delay reduces weight gain, which birds cannot compensate for by up to 21 days of rearing. Our experiment confirms these observations, since the average body weight of birds kept without additional feed application was lower at 21 days than that obtained in the experimental groups, by 6.1% and 7.4% relative to groups B and C, respectively. El-Husseiny et al. [2008] also indicated that delaying access to feed for 1 or 2 days significantly accelerates yolk sac absorption and reduces body weight gain of chickens in the first week of rearing. It is recommended to place feeders already in the hatcher to allow chicks to ingest feed immediately after hatching, as this period can often be considerably extended over time. It may happen that the difference in chicks hatching time may amount to 19 hours and thus expose chicks to starvation [Vieira et al. 2005]. In the studies of Obun and Osaguon [2013], the length of time to feed ingest was also negatively correlated with the production results of birds obtained during 28 days of rearing but did not affect chickens survivability. In our experiment, up to day 21, better liveability was observed in groups B and C.

Cengiz et al. [2012] evaluated production and physiological and developmental parameters of the Ross 308 chicken gastrointestinal tract following delayed first feed ingest. This manipulation significantly reduced the body weight of birds, relative gizzard weight and intestinal crypt depth. However, these changes were only visible at an early stage of rearing (up to about 10 days) and disappeared later. There were no differences in the proportion of particular carcass cuts. In our research, the highest carcass yield in 42-day-old chicks was found in group B, while in group C the lowest proportion of the breast muscle was found. Furthermore, it appears that an additional source of feed (paper) may contribute to an increase in gizzard weight. Wall et al. [2025] suggested that chickens are capable of compensating for 48 hours of feed and water deprivation post-hatch. It was stated

that 48-hour delay in first feed access resulted in smaller internal organs weights in 5-day-old birds, however, similarly to our observations, none of the differences persisted at the end of the study on day 43. Similarly, Boyner et al. [2025] found a considerably larger gizzard proportion in body weight in birds that were provided with access to feed and water immediately after hatching. However, by day 11 of life, no such difference was observed, whereas in our studies, the effect of additional feed administration persisted until day 42 of the broilers' life.

Another group of researchers assessed the possibility of periodic quantitative or qualitative restriction of broiler feed. Lippens et al. [2009] showed that a 4-day 20% reduction in feed supply (between day 3 and 7 after hatching) does not affect the final body weight of Ross 308 chickens. Additionally, higher body weight was observed in birds fed pelleted rather than mash feed. This confirms the justification for using pelleted feed for meat-type birds. However, feed restriction did not alter the results of carcass traits or their carcass yield in any of the groups. Jahanpour et al. [2015] even reported improvements in both body weight and slaughter parameters as a result of periodic (during the second or third week of rearing) dietary restrictions for broilers of up to 50 and 75% of their recommended daily intake. They recommended reduced diet programs as a useful strategy for broiler chicken management without reducing their slaughter value. In another study, Mohammad and Masoud [2015] indicated that when feed restriction (by 10, 20 or 30%) occurs at an early stage of development, the compensatory gain and, at the same time, the improvement in final productivity results are observed. In addition, feed restriction significantly contributes to the reduction of carcass fatness as indicated by abdominal fat pad size.

Nielsen et al. [2010] pointed to the possibility of differences in feed supply method depending on the meat-type chicken genotype and also suggested that the early transition from paper to feeders may be important for the smallest chicks. In their study, Ross 308, fast-growing chickens were compared to slow-growing birds. The percentage of birds engaged in feeding activity was similar, but slow-growing chicks began to eat from the paper later and were observed eating from the feeder less than fast-growing birds, which were less active, did not forage as actively and preferred a conventional feeder. Feed placed on paper was more easily accessible to chicks than feed provided by standard feeders which required movement to reach them. Access to feed dispensed on paper may also, to some extent, help to adjust the body weight of chicks that vary at the hatching stage, particularly when the hatching window is extended, as the earliest-hatched birds spend the longest time in the high-temperature conditions of the hatcher, lose the most water (body weight), and therefore have the lowest body weight [Lamot et al. 2014]. This highlights the importance of an additional feeding source due to Ross 308 chickens productivity depending on their initial body weight. Michalczuk et al. [2011] found that the smallest chicks, characterised at the same time by the highest growth rate, are not able to reach a similar final weight to heavier birds while maintaining the same rearing and feeding conditions.

CONCLUSIONS

Additional feed provisions on paper strips influenced chick survivability during the production cycle. However, in the first week of life, the main cause of mortality in experimental groups was yolk sac infection (resulted from incubation), while in the control group it was failure to initiate foraging. Total mortality did not differ between groups.

The use of grey corrugated cardboard/green waxed paper strips increased the body weight of broiler chickens, with the effect being particularly evident in the first three weeks of rearing. In group B (grey corrugated cardboard), birds exhibited the highest carcass yield and a significantly larger breast muscle proportion than those in the group provided with green paper. Furthermore, even in 6-week-old birds, improved gastrointestinal development, reflected by greater gizzard proportion was observed, which may have been associated with the additional feed source.

Thus, additional feeding of birds using cardboard or paper strips on litter has positive effects on their physiological development and final production results, with grey corrugated cardboard proving to be more effective in this respect.

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Role of corvids and foxes in predation on artificial nests of the common pheasant (*Phasianus colchicus*) in urban and agricultural environments

Abstract. Given the numerous factors negatively affecting small game populations, including ground-nesting birds, it is important to assess the potential impact of individual predators on the breeding success of these species. The study aimed to determine the predation pressure of corvids (Corvidae) and the red fox (*Vulpes vulpes*) on artificial nests of the common pheasant (*Phasianus colchicus*) in urban and agricultural areas using artificial nest experiments. The study was conducted in urban and agrarian areas from 2024 to 2025. A total of 60 artificial nests were analysed. The nests were located in typical pheasant breeding habitats, such as urban thickets, allotment gardens, field margins, fallow lands, and mid-field woodlots. In urban areas, the main predator responsible for nest destruction was the Eurasian magpie (*Pica pica*), accounting for 72% of destroyed nests. In agricultural landscapes, most nest damage was caused by the red fox (*Vulpes vulpes*), responsible for 66% of cases. The differences in the composition of predator groups between habitats indicate that landscape structure and the degree of human transformation determine both the composition and intensity of predation pressure, and consequently, the level of risk to pheasant nesting success.

Keywords: common pheasant, artificial nest, predator pressure, corvids, red fox

INTRODUCTION

The common pheasant (*Phasianus colchicus*), like other small game species, is exposed to the adverse effects of environmental changes such as agricultural intensification, landscape simplification and the expansion of monocultures [Czyżowski et al. 2017, Ponce et al. 2018, Kamieniarz 2022]. These

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changes reduce the availability of suitable nesting habitats, decrease cover, and increase predation pressure. Such factors can negatively affect reproductive success and, consequently, population size, particularly in ground-nesting bird species. Female pheasants lay their eggs in small ground depressions and incubate them alone for approximately 24–25 days [Bazewicz and Czyżowski 2019]. Ground nests are also threatened by synanthropic predators such as stray and free-roaming cats and dogs [Flis and Rataj 2019], as well as by corvids (Corvidae) such as the Eurasian magpie (*Pica pica*) [Czyżowski et al. 2006, Sage and Aebischer 2017, Capstick et al. 2019]. Nest predation is one of the main factors limiting populations of ground-nesting birds [Pass et al. 2019, Matysioková and Remeš 2024, Palencia and Barroso 2024]. Therefore, monitoring the impact of specific threats, especially predators, is justified. One method used for this purpose involves artificial nest experiments [Krüger et al. 2018]. Although such nests do not perfectly reflect the natural conditions of nesting birds, they help identify potential nest predators and areas at risk [Major and Kendal 1996]. Artificial nests also allow for repeatable observations, although destruction rates may differ from those of natural nests due to differences in egg size, colour, scent, or the absence of incubating birds, which in nature provide camouflage and scent masking [Burke et al. 2004]. Comparing urban and rural sites also helps assess synurbization processes – the adaptation of wildlife to urban environments – which is becoming increasingly widespread [Luniak 2004, Ditchkoff et al. 2006].

This study aimed to assess the predation pressure of corvids (Corvidae) and the red fox (*Vulpes vulpes*) on artificial nests of the common pheasant (*Phasianus colchicus*) in urban and agricultural areas.

MATERIALS AND METHODS

The study was conducted over two breeding seasons (2024–2025). Each year, 15 artificial nests were established in agricultural areas and 15 in urban areas. Each nest consisted of four small brown-shelled chicken eggs and one plasticine egg placed in a ground depression. Nests were randomly distributed, although the selection of sites took into account the presence of concealing vegetation to simulate natural nest locations. The nests were established between late April and early May in areas with known pheasant presence. The study area encompassed the city of Lublin and its surrounding areas, as well as the two rural communes of Mełgiew and Turobin. In urban areas, nests were placed in allotment gardens, a city park, and meadows near the Bystrzyca River. In rural areas, they were located in meadows, fallow lands, and mid-field woodlots. Each study area covered approximately 500 hectares, and the average distance between nests was 400 meters. Each nest was checked four times at weekly intervals. During each inspection, the number of damaged eggs, visible predator tracks, eggshell damage patterns, droppings, scent traces, and direct observations of predators were recorded. Every third nest was randomly selected for video monitoring. The degree of predation was expressed as the percentage of damaged eggs per nest.

Statistical analysis

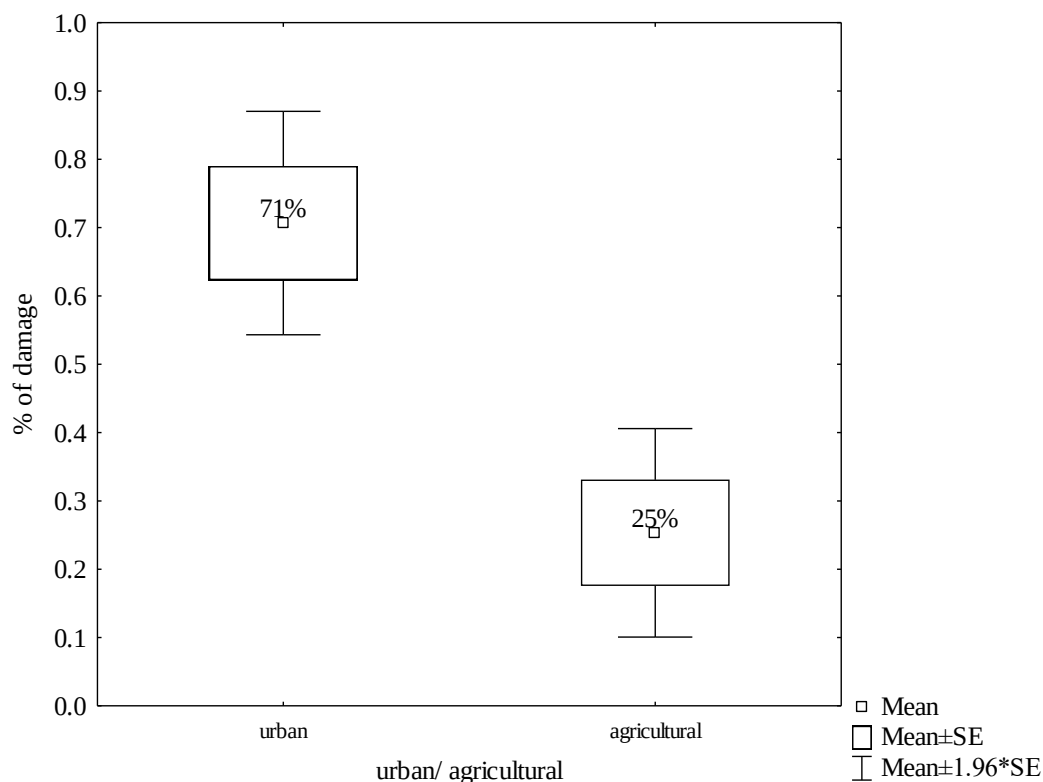
Differences in destruction rates (%) between urban and agricultural sites were tested using the non-parametric Mann–Whitney U test. The influence of environmental and spatial factors on nest destruction (%) was assessed using a linear mixed model (Mixed Model ANOVA) in Statistica 13.1. The dependent variable was the percentage of nest destruction. Fixed effects included nest location and predator species/cause of damage. Covariates included distance from single buildings, villages/compact housing, field–forest boundaries, magpie nests, and the number of magpies observed near nests.

All continuous variables were standardised ($z = (x - \mu) / \sigma$). Nest ID was treated as a random effect. Results were presented as F-values and corresponding p-values.

RESULTS

The analysis of the mean percentage of nest destruction showed that nests located in urban areas were destroyed significantly more often (mean 71%) than those in agricultural areas (mean 25%), as in Figure 1. The difference, assessed using the non-parametric Mann-Whitney U test, was statistically significant. These results are consistent with the mixed-model analysis, which also revealed a significant effect on the destruction rate ($F_{5,18} = 3.07$, $p = 0.036$), as in Table 1. This difference indicates that urban or suburban environments are characterised by higher predation pressure on artificial nests. This effect may result from the higher abundance of synanthropic predators – species well adapted to human presence, such as the Eurasian magpie (*Pica pica*), which are more common near human settlements. These species benefit from the abundance of food and convenient shelter sites near human habitation, which may increase the frequency of their visits to the nest surroundings.

Figure 1. Comparison of destruction rates (%) among artificial nests located in urban and agricultural areas during the study period



U Mann-Whitney test $Z = 3.125$, $p = 0.0018$

The mixed-model analysis revealed that the strongest factor influencing the percentage of destroyed nests was proximity to individual buildings – nests located closer to buildings were more likely to be damaged. This may reflect higher predator activity near human settlements or easier access to the nests. The percentage of destroyed artificial nests was significantly related to the distance from individual buildings ($F_{1,18} = 17.57$, $p < 0.001$) and nest location ($F_{5,18} = 3.07$, $p = 0.036$), as in Table 1.

The effect of predator species was close to statistical significance ($F_{2,18} = 2.80$, $p = 0.087$), suggesting that different predator types may have contributed to nest destruction to varying degrees.

Other spatial variables, including distance from villages or compact buildings, distance from field–forest boundaries, distance from magpie nests, and the number of magpies near nests, showed no significant effects ($p > 0.05$).

Table 1. Results of the analysis of variance (ANOVA) for the mixed model with fixed and random effects, analysing the influence of selected environmental components on the percentage of destroyed artificial nests

Variable	Effect	MS	F	p
Distance from individual buildings	covariates	0.422	17.573	0.001*
Distance from the village or compact buildings	covariates	0.007	0.286	0.599
Distance from the field/forest boundary	covariates	0.075	3.112	0.095
Distance from magpie nest	covariates	0.016	0.651	0.430
Number of magpies	covariates	0.030	1.270	0.274
Nest location	fixed	0.074	3.066	0.036*
Cause or predator of the damage	fixed	0.067	2.798	0.087
Nest no.	random	0.024		

*significant for $p \leq 0.05$

Although the mixed model showed only a moderate effect of predator species, some differentiation was observed.

In urban environments, the dominance of corvids, such as the magpie (*Pica pica*), is typical of anthropogenic landscapes (Figure 2). This species is well-adapted to human presence, and its abundance and foraging activity increase in built-up areas. The high proportion of nest destruction caused by corvids in urban environments (72%) suggests that these birds are the primary nest predators in urbanised landscapes. In contrast, the most frequent predator in agricultural landscapes was the red fox (*Vulpes vulpes*, 66%), a typical ground predator of open habitats. Its predominance in rural environments reflects habitat structure and easier access to nests placed close to the ground. The relatively small share of corvids (18%) in agricultural areas suggests that the activity of avian predators there is more scattered and limited by the lower availability of suitable observation points.

Unidentified cases of destruction (16%) in agricultural habitats may have resulted from the absence of clear feeding traces or from predation by other, less common species (e.g. martens or hedgehogs), whose presence was difficult to confirm.

The dominant predator type depended on habitat structure and the degree of anthropogenic influence (Figure 3). In habitats strongly associated with human activity, such as urban parks or allotment gardens, the primary predators were corvids (Corvidae), which are well-adapted to urban environments. Their presence is related to high availability of food resources and convenient observation points (e.g. trees, lamp posts, fences). The high percentage of nest destruction caused by corvids in urban habitats (67–100%) supports their dominant role in nest predation within urban landscapes. In contrast, in more natural or semi-natural habitats such as wastelands and forests, red foxes predominated, accounting for 100% and 75% of nest destruction, respectively. This reflects their preference for areas with denser vegetation and less human presence, where they can move freely and track scents. Meadows and field margins represented transitional habitats – here, both predator groups co-occurred. Corvids predominated on meadows (89%), while on field margins the contribution of different

predators was more balanced, with a high percentage of unidentified cases (46%). This suggests that margins may serve as zones of overlapping activity for both ground and avian predators, whose traces are often difficult to distinguish.

Figure 2. Percentage share of identified nest predators in the compared environments

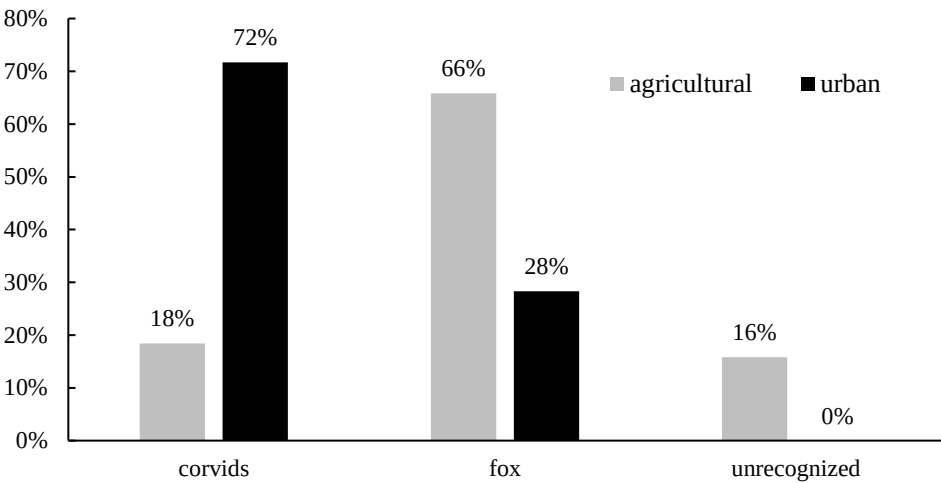
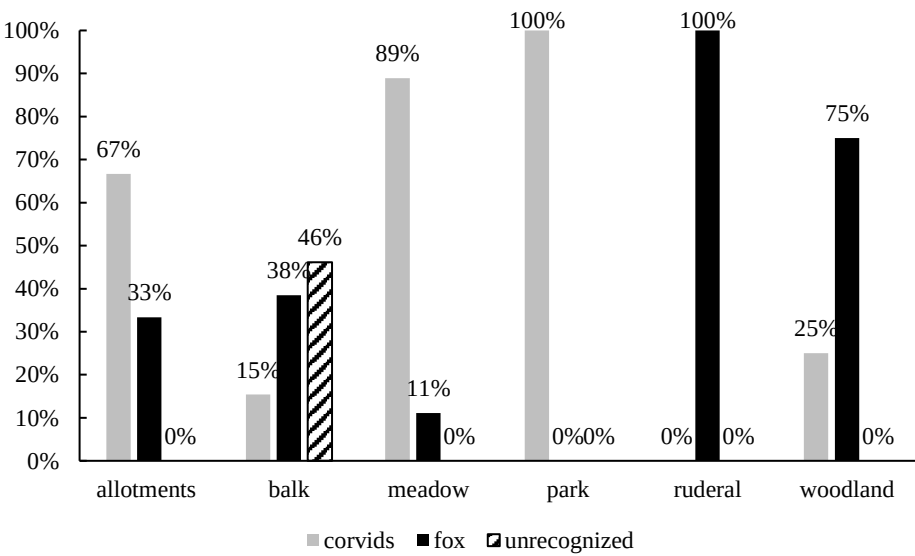


Figure 3. Proportion of predators responsible for nest destruction by habitat type



DISCUSSION

Our study clearly demonstrates significant differences in predation pressure between urban and agricultural habitats. Corvids, especially the Eurasian magpie, were the main nest predators in urban areas, whereas on farm areas the red fox predominated. These results align with previous findings from Poland [Bazewicz and Czyżowski 2019, Czyżowski et al. 2025] as well as other studies [Capstick et al. 2019, Morozov 2022, Jokimäki and Kaisanlahti-Jokimäki 2025]. Pheasants, which often occupy ecotone

zones at habitat edges during the breeding season, are particularly vulnerable to opportunistic predators such as foxes and corvids [Storch et al. 2005, Draycott et al. 2008, Šálek et al. 2010].

The observed habitat-based differences suggest that landscape structure and the degree of urbanisation significantly influence predator composition and predation risk. Synurbization – the adaptation of wild species to urban environments – is now a well-documented ecological process [Luniak 2004, Ditchkoff et al. 2006, Kurucz et al. 2021]. Species such as magpies benefit from abundant food sources and numerous vantage points (trees, lamp posts, fences), which facilitate nest detection [Jokimäki and Kaisanlahti-Jokimäki 2025].

The high destruction rate in urban habitats (mean 71%) confirms the successful adaptation of corvids to urban conditions. Their opportunistic foraging patterns, high intelligence, and problem-solving ability make them effective nest predators [Dupak and Telizhenko 2023]. In contrast, the red fox – a typical terrestrial predator of open areas – was responsible for most nest losses in rural habitats [Baker et al. 2006].

The significant effect of proximity to individual buildings on nest destruction suggests that anthropogenic infrastructure indirectly increases predation pressure by attracting synanthropic predators such as magpies, foxes, and cats [Morozov 2022, Ma et al. 2025]. Although the number and distance of magpie nests were not statistically significant, these variables may not accurately capture foraging intensity, which depends on food availability and vegetation structure [Sage and Aebischer 2017, Capstick et al. 2019].

The differences in predator composition between habitats highlight the need for habitat-specific management strategies to protect pheasant nests. In urban areas, measures limiting corvid access to nesting sites (e.g. vegetation management) may be more effective. In contrast, in rural areas, efforts should focus on controlling terrestrial predator populations, particularly foxes [Benmazouz et al. 2021].

SUMMARY AND CONCLUSIONS

The results indicate that predation pressure on artificial pheasant nests was significantly higher in urban than in agricultural areas. The most important environmental factor influencing nest destruction was proximity to buildings, confirming the role of anthropogenic elements in shaping predator activity. In urban landscapes, corvids – especially the highly synurbized Eurasian magpies (*Pica pica*) – were the dominant predators, whereas in rural areas, the red fox (*Vulpes vulpes*) was the prevailing species. The variation in predator groups between habitats demonstrates that landscape structure and the degree of human modification determine predator composition and intensity, thus influencing the breeding success of the common pheasant. These findings emphasise the importance of considering spatial and urbanisation factors when assessing causes of reproductive failure in ground-nesting bird species.

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Noise exposure assessment for operator in agricultural tractor cabs

Ocena narażenia operatora na hałas w kabinach ciągników rolniczych

Abstract. The aim of the study was to assess the sound level inside the cabins of agricultural tractors. The research covered a group of tractors differing in engine power, mileage, and year of manufacture. The results were compared in terms of engine power, minimum and maximum sound levels, the newest and oldest tractor, as well as the sound level inside and outside the cabin. The measurements were made in accordance with the Polish norm PN-EN ISO 9612:2011. Additionally, selected tractors were tested while towing equipment such as a sprayer or a trailer. Based on the conducted tests, it was found that tractors manufactured after the year 2000 provide better sound insulation and greater operator comfort. In contrast, the oldest tractors, due to long-term use and lack of maintenance, no longer meet cabin tightness requirements, which increases the operator's exposure to noise.

Abbreviations: dB – decibel; HP – horsepower; mth – machine operating hours; rpm – revolutions per minute; PPE – personal protective equipment; L_{Aeq} – A-weighted equivalent continuous sound level; L_{ASmax} – maximum A-weighted sound level with slow time weighting; L_{Cpeak} – peak C-weighted sound level; $L_{EX,8h}$ – daily noise exposure level normalized to an 8-hour working day; $L_{Aeq,Te}$ – A-weighted equivalent continuous sound level during the effective exposure period; L_{peak} – peak sound level; L_{max} – maximum sound level; L_{min} – minimum sound level; IMPULSE – impulse time weighting; FAST – fast time weighting; SLOW – slow time weighting

Key words: noise, environmental pollution, environmental protection, agriculture, machinery

INTRODUCTION

Occupational work can pose a variety of hazards that negatively affect human health. One such hazard is noise, whose detrimental impact has been documented on several physiological systems, including the digestive and cardiovascular systems [Bortkiewicz et al. 2018]. Excessive noise levels may

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lead to hearing impairment and are also associated with tension, irritability, and decreased concentration [Kirpluk 2003, 2024, Bortkiewicz et al. 2018]. Noise is inherent in nearly all sectors of a developing economy, including agriculture, where one of the primary sources of noise is agricultural machinery. Recent studies emphasize that long-term exposure to noise generated by agricultural machinery remains a significant occupational risk, and that ergonomic improvements in machinery design can help reduce, but not completely eliminate, this hazard [Di Stefano et al. 2025, Mushtaq et al. 2025]. The intensity of noise exposure depends largely on the technical condition of the equipment, particularly the engine quality and operating lifespan. Poorly maintained or low-quality machinery not only contributes to excessive noise but also increases the likelihood of occupational accidents, including falls, fractures, electric shocks, entanglement in machinery, and fatalities. Such incidents are frequently attributed to insufficient awareness among farmers regarding occupational risks, a lack of occupational health and safety (OHS) training, inadequate education, and noncompliance with manufacturers' operational guidelines.

In the agricultural sector, health and safety risks remain pervasive due to the diverse range of tasks performed by individual farmers during a typical workday. Workplace safety practices, hygiene protocols, and preventive medical examinations are often neglected by agricultural workers, which reflects a general lack of awareness regarding occupational hazards [Jaśkowiec and Stopa 2016]. According to data from the Agricultural Social Insurance Fund (KRUS), the number of reported agricultural accidents has shown a downward trend. In 2023, a total of 10,709 occupational accidents were reported – 940 cases (8.1%) fewer than in 2022 – accompanied by a 4.6% decrease in the number of insured persons (49,640 fewer). Since 2014, the number of reported accidents has declined by over 50% (11,230 cases, 51.2%), while the number of insured persons has fallen by 400,335 (27.9%) [KRUS 2024]. Under the provisions of the Farmers' Social Insurance Act, 10,111 incidents were classified as occupational accidents in agriculture, representing a 5.2% decrease (556 cases) compared to the previous year. The number of fatal accidents in the three-year period from 2021 to 2023 totaled 45, compared with 77 cases in 2014 [KRUS 2024]. The most frequent causes of fatal accidents included being run over, struck, or caught by a moving vehicle, with the following specific cases reported: tractor rollovers (8 cases), combine harvester rollover (1 case), run-over incidents involving agricultural tractors (3 cases), and road traffic accidents (3 cases) [KRUS 2024]. It should be noted that the average nominal power of tractors, expressed in kilowatts (kW), increased from 37.9 kW in 2010 to 46.9 kW in 2020, representing a rise of more than 20% [GUS 2024]. The objective of this study was to compare the operator's exposure to noise inside the cabins of agricultural tractors across various tractor models. The evaluated machines differed in engine power, operational mileage, and service life.

MATERIAL AND METHODS

The noise level measurements in agricultural tractors were conducted on a farm located in the Tomaszów County. The farm specializes in crop production, primarily cultivating winter and spring wheat, sugar beet, and winter rapeseed.

A total of fourteen agricultural tractors used on the farm were included in the study. The comparison of the tested tractors was organized according to the engine power criterion (Table 1). To ensure that the measurements reflected real operating conditions, the tractors were tested under typical load scenarios commonly used by the farmers on the site. For this purpose, an Autosan trailer with a payload capacity of 8 tonnes and a Pilmet trailed sprayer with a tank capacity of 2000 liters were employed during the measurements.

The measurements were conducted in the first half of May 2023 under the following meteorological conditions:

- relative air humidity: 30–34%

- air temperature: 24–26°C
- wind speed: approximately 5 m/s.

The study employed a digital sound level meter SVAN 955 (Class 1) manufactured by Svantek (Figure 1). This instrument is designed for acoustic measurements, including environmental and occupational noise assessments. The device enables the measurement of various sound parameters (e.g., L_{peak} , L_{max} , L_{min} , etc.) within a frequency range of 20 Hz to 20 kHz, with a sampling rate of 48 kHz, and allows the use of time weightings (IMPULSE, FAST, SLOW) as well as frequency weighting filters A, C, and Z [Svantek 2009].

Table 1. List of agricultural tractors used for noise level assessment

No.	Model	Power (HP)	Year of manufacture	Operating hours (mth)	Remarks/Load
1	Ursus C3603P	47	1988	5 000	no cabin
2	Ursus C360	52	1978	10 000	no cabin
3	Ursus C385	76	1971	20 000	–
4	Case 844XL	84	1996	9 000	sprayer
5	Case 956XL	95	1989	12 000	–
6	John Deere 6230	95	2013	1 100	sprayer
7	Case 1056XL	105	1989	11 350	–
8	Fendt Favorit 711	115	2001	7 500	–
9	Case 5140	120	1991	14 000	–
10	Ursus 1634	120	1995	9 000	–
11	John Deere 6520	120	2003	4 000	–
12	John Deere 6930	155	2011	2 720	trailer
13	Case MX170	170	1999	9 150	–
14	John Deere 6170M	170	2015	1 580	trailer

Two independent measurement series were carried out to confirm the accuracy and repeatability of the results. Prior to each measurement session, the instrument was calibrated according to the manufacturer's instructions.

Noise level measurements were performed inside and outside each tractor (at a distance of 7 m in front of the machine). Inside the cabin, measurements were taken at the operator's head height, under the following operating conditions: idle speed, engine speed of 2000 rpm, during driving on a 100 m flat section of road at a speed of 5 km/h, both with and without load.

In four cases, measurements were conducted under additional load conditions, with the tractor connected to either a trailer or a sprayer. Detailed information regarding the tested tractors and loading conditions is presented in Table 1.

The noise exposure level inside the tractor cabin, normalized to an 8-hour workday $L_{EX,8h}$ is presented in Table 5. It was assumed that the tractor operator's actual working time amounted to 6 hours. Two of the tractors tested were not equipped with cabins, and these were treated as exceptions in the analysis. To determine the daily noise exposure level $L_{EX,8h}$ the following equation was applied:

$$L_{EX,8h} = L_{Aeq,T_e} + 10 \cdot \log\left(\frac{T_e}{T_o}\right), [\text{dB}]$$

where:

$L_{EX,8h}$ – noise exposure level normalized to an 8-hour working day,

L_{Aeq,T_e} – A-weighted equivalent continuous sound level for the effective working period (dB),

T_e – duration of noise exposure (6 hours),

T_o – reference time period (8 hours).

Figure 1. SVAN 955 Class 1 sound level meter [photo: P. Maksym]



In addition to arithmetic mean values, the standard deviation (SD) was calculated for each measurement series in order to assess the variability and repeatability of the recorded noise levels.

RESULTS AND DISCUSSION

In the tables presented below (Tables 2–4), the following additional symbols and abbreviations are used:

- * – tractor not equipped with a cabin,
- N – measurement taken outside the tractor,
- W – measurement taken inside the tractor cabin,
- O – tractor loaded with a sprayer during operation,
- P – tractor loaded with a trailer during operation.

Table 2. Measured sound levels of tractors at a frequency of 1000 Hz, based on L_{Aeq} — equivalent continuous sound level with slow time weighting

No.	Model	Measurement location	Idle speed	Engine speed 2000 (rpm)	During driving
			(dB $\pm$ SD)	(dB)	(dB)
1.	Ursus C3603P*	N	68,0 $\pm$ 0,141	79,2 $\pm$ 0,212	78,2
		W	74,6 $\pm$ 0,071	87,0 $\pm$ 0,141	92,2
2.	Ursus C360*	N	74,7 $\pm$ 0,071	80,0 $\pm$ 0,354	73,6
		W	72,4 $\pm$ 0,354	89,4 $\pm$ 0,141	86,3
3.	Ursus C385	N	74,9 $\pm$ 0,425	88,0 $\pm$ 0,495	80,3
		W	71,6 $\pm$ 0,283	81,7 $\pm$ 0,141	80,7
4.	Case 844XL	N	66,2 $\pm$ 0,141	81,4 $\pm$ 0,354	79,8 O
		W	61,9 $\pm$ 0,071	76,0 $\pm$ 0,141	74,6 O
5.	Case 956XL	N	69,0 $\pm$ 0,779	82,4 $\pm$ 0,708	78,6
		W	60,7 $\pm$ 0,071	72,0 $\pm$ 0,141	73,5
6.	John Deere 6230	N	62,0 $\pm$ 0,212	74,5 $\pm$ 0,495	69,2 O
		W	58,1 $\pm$ 0,212	62,4 $\pm$ 0,495	61,9 O
7.	Case 1056XL	N	70,1 $\pm$ 0,071	80,5 $\pm$ 0,0	77,8
		W	67,2 $\pm$ 3,587	70,2 $\pm$ 0,354	73,1
8.	Fendt Favorit711	N	63,4 $\pm$ 0,141	72,0 $\pm$ 0,071	69,1
		W	52,6 $\pm$ 0,071	60,0 $\pm$ 0,212	59,6
9.	Case 5140	N	77,7 $\pm$ 0,283	89,1 $\pm$ 0,851	79,6
		W	69,1 $\pm$ 0,495	78,7 $\pm$ 0,0	76,8
10.	Ursus 1634	N	69,8 $\pm$ 0,141	81,3 $\pm$ 0,071	74,2
		W	67,2 $\pm$ 0,354	77,9 $\pm$ 0,212	77,0
11.	John Deere 6520	N	73,1 $\pm$ 0,212	83,7 $\pm$ 0,354	79,0
		W	53,3 $\pm$ 0,0	66,4 $\pm$ 0,071	65,0
12.	John Deere 6930	N	68,0 $\pm$ 0,354	74,8 $\pm$ 0,283	70,8 P
		W	61,2 $\pm$ 0,071	65,7 $\pm$ 0,141	65,1 P
13.	Case MX170	N	80,2 $\pm$ 0,0	86,8 $\pm$ 0,141	76,2
		W	60,1 $\pm$ 0,708	64,5 $\pm$ 0,354	63,9
14.	John Deere 6170M	N	64,2 $\pm$ 0,283	74,0 $\pm$ 0,495	72,1 P
		W	54,5 $\pm$ 0,283	63,7 $\pm$ 1,208	60,6 P

The lowest measured value was 54.5 dB at idle speed, while the highest recorded value reached 92.2 dB, which exceeds the permissible exposure limit of 85 dB.

Table 3. Measured sound levels of tractors. L_{ASmax} – maximum A-weighted sound level with SLOW time weighting

No.	Model	Measurement location	Idle speed	Engine speed 2000 (rpm)	During driving
			(dB $\pm$ SD)	(dB)	(dB)
1.	Ursus C3603P*	N	73,1 $\pm$ 0,354	85,1 $\pm$ 0,141	92,0
		W	78,0 $\pm$ 0,283	92,0 $\pm$ 0,212	96,0
2.	Ursus C360*	N	66,9 $\pm$ 0,071	84,8 $\pm$ 0,141	85,0
		W	77,3 $\pm$ 0,071	94,2 $\pm$ 0,071	95,0
3.	Ursus C385	N	81,6 $\pm$ 0,637	92,4 $\pm$ 0,0	93,0
		W	77,9 $\pm$ 0,071	90,1 $\pm$ 0,637	87,0
4.	Case 844XL	N	70,7 $\pm$ 0,283	87,2 $\pm$ 0,071	92,4 O
		W	67,6 $\pm$ 0,993	81,7 $\pm$ 0,283	91,4 O
5.	Case 956XL	N	72,2 $\pm$ 0,212	86,5 $\pm$ 0,071	90,0
		W	67,2 $\pm$ 1,136	76,8 $\pm$ 0,495	79,0
6.	John Deere 6230	N	68,8 $\pm$ 0,708	81,3 $\pm$ 0,141	79,9 O
		W	81,1 $\pm$ 0,283	69,0 $\pm$ 0,708	69,2 O
7.	Case 1056XL	N	74,9 $\pm$ 0,637	86,7 $\pm$ 0,141	88,0
		W	80,4 $\pm$ 12,082	77,1 $\pm$ 1,858	79,0
8.	Fendt Favorit711	N	71,1 $\pm$ 1,065	78,6 $\pm$ 0,071	79,0
		W	66,9 $\pm$ 4,058	69,3 $\pm$ 1,858	67,0
9.	Case 5140	N	82,7 $\pm$ 1,640	95,1 $\pm$ 1,065	91,0
		W	74,3 $\pm$ 0,212	85,4 $\pm$ 0,922	83,0
10.	Ursus 1634	N	73,7 $\pm$ 0,0	86,4 $\pm$ 0,0	87,0
		W	72,0 $\pm$ 0,212	83,5 $\pm$ 0,071	83,0
11.	John Deere 6520	N	79,4 $\pm$ 0,071	89,8 $\pm$ 1,136	91,0
		W	62,2 $\pm$ 0,922	71,6 $\pm$ 0,212	71,0
12.	John Deere 6930	N	79,4 $\pm$ 0,212	81,0 $\pm$ 0,071	83,5 P
		W	71,0 $\pm$ 1,496	71,0 $\pm$ 0,0	72,5 P
13.	Case MX170	N	91,1 $\pm$ 0,0	88,0 $\pm$ 0,0	88,0
		W	76,4 $\pm$ 3,743	72,0 $\pm$ 0,425	72,0
14.	John Deere 6170M	N	79,9 $\pm$ 0,708	83,0 $\pm$ 0,637	83,6 P
		W	68,1 $\pm$ 0,354	67,0 $\pm$ 0,354	67,5 P

The maximum permissible sound level is 115 dB. Analysis of the results indicates that none of the measurements exceeded this threshold.

The peak sound levels ranged from 86.5 dB to 115.4 dB. These represent the highest recorded values compared with the previous measurements; however, they do not pose a health risk, as they remain below the permissible limit of 135 dB.

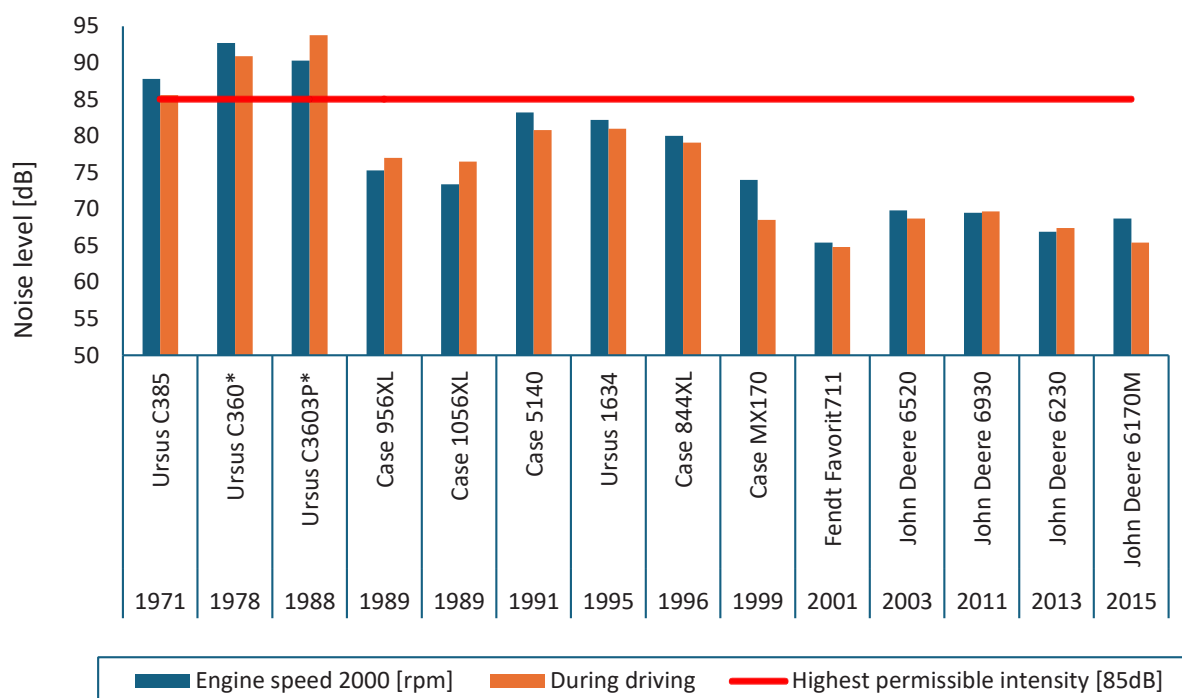
Table 4. Measured sound levels of tractors. L_{Cpeak} — peak C-weighted sound level

No.	Model	Measurement location	Idle speed	Engine speed 2000 (rpm)	During driving
			(dB $\pm$ SD)	(dB)	(dB)
1.	Ursus C3603P*	N	95,7 $\pm$ 0,354	105,3 $\pm$ 0,354	112,1
		W	101,1 $\pm$ 0,212	115,0 $\pm$ 0,283	115,4
2.	Ursus C360*	N	89,5 $\pm$ 0,141	104,4 $\pm$ 0,425	102,7
		W	100,7 $\pm$ 0,425	113,4 $\pm$ 0,071	117,1
3.	Ursus C385	N	99,1 $\pm$ 0,566	109,7 $\pm$ 0,566	111,0
		W	102,4 $\pm$ 0,212	112,8 $\pm$ 0,566	105,9
4.	Case 844XL	N	91,2 $\pm$ 0,354	104,4 $\pm$ 0,141	107,7 O
		W	95,6 $\pm$ 0,141	102,0 $\pm$ 0,851	112,9 O
5.	Case 956XL	N	92,4 $\pm$ 0,495	102,1 $\pm$ 0,071	105,4
		W	92,8 $\pm$ 0,708	96,4 $\pm$ 0,212	107,4
6.	John Deere 6230	N	97,3 $\pm$ 0,851	99,3 $\pm$ 0,283	98,3 O
		W	98,9 $\pm$ 0,071	94,2 $\pm$ 1,785	101,4 O
7.	Case 1056XL	N	92,9 $\pm$ 1,065	102,6 $\pm$ 0,354	103,2
		W	115,5 $\pm$ 17,192	93,2 $\pm$ 0,283	104,2
8.	Fendt Favorit711	N	94,0 $\pm$ 0,495	96,3 $\pm$ 0,212	100,0
		W	93,5 $\pm$ 1,858	93,0 $\pm$ 0,283	96,9
9.	Case 5140	N	101,5 $\pm$ 2,672	111,5 $\pm$ 1,568	107,5
		W	98,3 $\pm$ 0,283	108,4 $\pm$ 0,851	106,5
10.	Ursus 1634	N	96,3 $\pm$ 2,373	102,8 $\pm$ 0,637	103,1
		W	97,7 $\pm$ 0,141	101,8 $\pm$ 0,071	105,1
11.	John Deere 6520	N	95,1 $\pm$ 0,708	102,2 $\pm$ 0,283	106,0
		W	90,0 $\pm$ 0,566	93,5 $\pm$ 0,141	102,7
12.	John Deere 6930	N	89,7 $\pm$ 0,708	96,9 $\pm$ 0,566	100,1 P
		W	91,2 $\pm$ 0,071	101,4 $\pm$ 1,208	108,4 P
13.	Case MX170	N	101,5 $\pm$ 0,851	106,9 $\pm$ 0,425	102,7
		W	100,2 $\pm$ 8,292	96,6 $\pm$ 0,141	99,5
14.	John Deere 6170M	N	92,4 $\pm$ 2,299	96,5 $\pm$ 0,922	99,2 P
		W	86,5 $\pm$ 0,354	94,6 $\pm$ 0,495	100,8 P

Table 5. Noise exposure levels measured inside selected tractor cabins, normalized to an 8-hour working day, determined on the basis of the equivalent continuous sound level $L_{Aeq,6h}$

No.	Model	$L_{EX,8h}$	
		Engine speed 2000 (rpm)	During driving
		(dB $\pm$ SD)	(dB)
1.	Ursus C3603P*	90,3 $\pm$ 0,071	93,8
2.	Ursus C360*	92,7 $\pm$ 0,212	90,9
3.	Ursus C385	87,8 $\pm$ 0,071	85,6
4.	Case 844XL	80,0 $\pm$ 0,141	79,1
5.	Case 956XL	75,3 $\pm$ 0,071	77,0
6.	John Deere 6230	66,9 $\pm$ 0,354	67,4
7.	Case 1056XL	73,4 $\pm$ 0,283	76,5
8.	Fendt Favorit711	65,4 $\pm$ 0,141	64,8
9.	Case 5140	83,2 $\pm$ 0,495	80,8
10.	Ursus 1634	82,2 $\pm$ 0,141	81,0
11.	John Deere 6520	69,8 $\pm$ 0,212	68,7
12.	John Deere 6930	69,5 $\pm$ 0,425	69,7
13.	Case MX170	74,0 $\pm$ 0,566	68,5
14.	John Deere 6170M	68,7 $\pm$ 0,141	65,4

Figure 2. Comparison chart of noise levels depending on the year of tractor production



The obtained results may be interpreted in relation to the requirements of Directive 2009/76/EC, which defines the maximum permissible sound pressure level at the operator's position in tractor cabins as 85 dB(A) during operation.

When the measured values are normalized to an 8-hour working day, it can be observed that more than half of the tractors fall within safe operating limits. However, for three machines, the measured noise levels exceeded the permissible value of 85 dB. The remaining tractors exhibited noise levels between 80 and 85 dB, placing them at the threshold of acceptability. The issue of noise in agricultural machinery has frequently been addressed in scientific research, particularly in the works of Professor Solecki [Solecki 1995]. In his habilitation thesis, the author examined the exposure of farmers to harmful noise generated by mechanical devices. In subsequent studies, he conducted an ergonomic evaluation of tractor operator work conditions, along with optimization strategies to improve them [Solecki 2002]. Studies by Adamczyk [2004, 2005] entitled "Noise of tractors under field conditions" demonstrated that the engine is the primary source of noise. The propagation of sound was analyzed across different tractor types and distances from the source. Spectral analysis in octave bands revealed that high-frequency noise (4000–16000 Hz) decreases most rapidly with distance, whereas low-frequency noise (63–125 Hz) diminishes much more slowly. Similar observations were made in the present study, particularly when comparing results in the octave band centered at 1000 Hz – a frequency close to that of human speech—used to assess interior noise levels of tractors idling at rest. The quietest tractors exhibited measured sound levels of 52.6 dB, 53.3 dB, and 54.5 dB, which were significantly lower than those recorded at the 31.5 Hz center frequency band (80.4 dB, 78.7 dB, and 74.2 dB, respectively). Recent studies indicate that although modern tractor cabins reduce noise levels, they do not fully eliminate operator exposure, especially under real working conditions [Durczak and Rybacki 2023, Marques and Lanças 2022]. In the study by Olszewski and Lachowska (2020), the authors identified several factors contributing to hearing loss following occupational noise exposure, with particular emphasis on farmers as a high-risk group. The problem becomes especially pronounced during intensive fieldwork periods, when weather-dependent scheduling limits the possibility of taking breaks due to time pressure. The nature of agricultural work, conducted in direct proximity to tractors and machinery, makes the elimination or isolation of noise sources largely impractical. Furthermore, personal protective equipment (PPE) often proves ineffective or inconvenient, as farmers need to receive auditory signals from different machines and environmental cues during operation.

SUMMARY

Noise is present in virtually every work environment, but machine operators and technical personnel are particularly exposed to its harmful effects. Agricultural machinery is an outcome of technological progress aimed at improving farmers' productivity and comfort. However, in less-developed farms, maintenance neglect and the failure to use hearing protection remain common issues during field operations.

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