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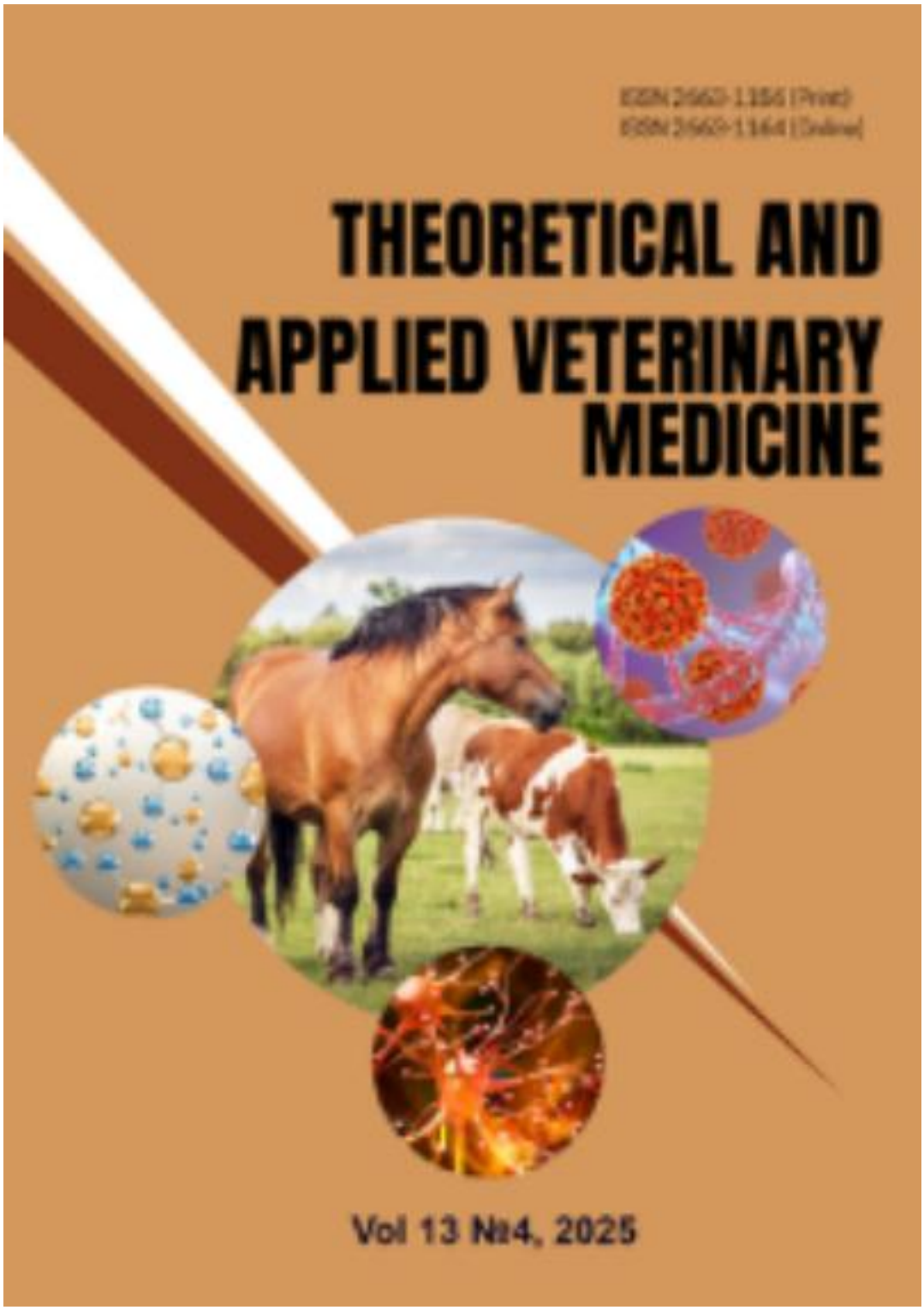

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Original research

Comparative assessment of dietary sorbents effect on pig growth performance

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Abstract. Mycotoxin contamination of feed represents a significant challenge in pig production, negatively affecting animal health, growth performance, and economic efficiency. The aim of this growth performance trial was to evaluate and compare the effectiveness of several mycotoxin sorbents of domestic and foreign origin in pig feeding under commercial production conditions. A 26-day trial was conducted using 52 pigs (Large White × Landrace hybrids) divided into four groups (n = 13): one control group received the basal diet, whereas three experimental groups received the same diet supplemented with one of three selected sorbents differing in their principal components, each administered at a dosage of 2 kg per ton of feed. Growth performance indicators, feed conversion ratio, and estimated economic parameters were analyzed. At the end of the trial, pigs receiving diets supplemented with sorbents tended to show higher body weight compared with the control group. The largest differences were observed in the P-exp and C-exp groups, where mean body weight reached 155.31 kg and 157.23 kg, respectively, compared with 140.92 kg in the control group. A similar tendency was noted for feed conversion ratio, which was comparatively lower in the P-exp (2.28) and C-exp (2.21) groups compared with the control group (3.96). These trends were also reflected in the calculated economic indicators, where lower estimated costs of weight gain and higher profitability were observed in the corresponding experimental groups. The present results have shown that the effect of mycotoxin sorbents may vary depending on their composition and functional components. Further research is required to evaluate the detailed mechanisms of individual components and to assess their effect under different feeding conditions and production systems.

Keywords: swine farming; mycotoxins; growth performance; profitability; sorbents.

Порівняльна оцінка впливу харчових сорбентів на показники росту свиней

Анотація. Забруднення кормів мікотоксинами становить значну проблему у свинарстві, негативно впливаючи на здоров'я тварин, показники росту та економічну ефективність. Метою цього дослідження показників росту було оцінити та порівняти ефективність кількох сорбентів мікотоксинів вітчизняного та іноземного походження у годівлі свиней у комерційних умовах виробництва. Було проведено 26-денне дослідження з використанням 52 свиней (гібриди великої білої породи × ландрас), розділених на чотири групи (n = 13): одна контрольна група отримувала базовий раціон, тоді як три експериментальні групи отримували той самий раціон, доповнений одним із трьох вибраних сорбентів, що відрізнялися за основними компонентами, кожен з яких вводився в дозі 2 кг на тонну корму. Були проаналізовані показники росту, коефіцієнт конверсії корму та розрахункові економічні параметри. Наприкінці дослідження свині, які отримували раціони з сорбентами, мали тенденцію до вищої маси тіла порівняно з контрольною групою. Найбільші відмінності спостерігалися в групах P-exp та C-exp, де середня маса тіла досягла 155,31 кг та 157,23 кг відповідно, порівняно зі 140,92 кг у контрольній групі. Подібна тенденція спостерігалася для коефіцієнта конверсії корму, який був порівняно нижчим у групах P-exp (2,28) та C-exp (2,21) порівняно з контрольною групою (3,96). Ці тенденції також відобразилися на розрахованих економічних показниках, де у відповідних експериментальних групах спостерігалися нижчі розрахункові витрати на приріст ваги та вища рентабельність. Наведені результати показали, що вплив сорбентів мікотоксинів може змінюватися залежно від їх складу та функціональних компонентів. Необхідні подальші дослідження для оцінки детальних механізмів дії окремих компонентів та оцінки їхнього впливу за різних умов годівлі та виробничих схем.

Ключові слова: свинарство; мікотоксини; приріст; рентабельність; сорбенти.

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Introduction

Mycotoxin contamination of animal feed represents a significant challenge for modern livestock production due to its negative effects on animal health, productivity, and economic performance. Fungal toxins are harmful biogenic compounds capable of accumulating in the organism and exerting embryotoxic, teratogenic, and carcinogenic effects, which may manifest as both acute and chronic disorders in animals (Malczak et al., 2025). Contamination of feed with mycotoxins poses a particularly serious threat to swine production, as pigs are considered one of the most sensitive livestock species to these toxins (Puvača et al., 2024). In addition to affecting animal health, mycotoxins may contaminate pork products, thereby posing potential risks to human health (Reshetnichenko et al., 2021). Consequently, mycotoxin contamination leads to substantial economic losses associated with reduced animal performance, increased veterinary costs, and decreased product quality.

Integrative detection of various mycotoxins demonstrated a high risk of feed contamination for both swine and poultry farming (Nualkaw et al., 2020; Kövesi et al., 2020). Feed contamination with mold saprophytes adversely affects many vital functions, including immunity, and the integrity of epithelial and endothelial barriers (Yang et al., 2020; Md Atiqual et al., 2020; Tassis et al., 2024). Thus, the study of the sorbents features with respect to binding mycotoxins has remained relevant over the last decades, with the few commercial sorbents demonstrating the potential protective effect against mycotoxins contamination (Patyal et al., 2020; Puvača et al., 2024). In particular, the sorption based on carbon nanotechnology was described as a promising component for binding mycotoxins (Ying et al., 2013). Another prospective strategy is an application of sorbent and bioactive components blend that provides multiple beneficial effects against toxins (Gruber-Dorninger et al., 2019; Nedzvetsky et al., 2020). In addition, natural sorbents supplementation has been reported to stimulate digestibility of dietary fiber, and activate metabolism in liver, kidneys and gut (Wlazło et al., 2023). However, comparative analyses of complex sorbent formulations remain scarce in the literature.

To mitigate the adverse effects of mycotoxins in feed, various preventive approaches have been developed, among which the use of mycotoxin adsorbents is one of the most widely applied strategies in livestock production (Ahn et al., 2022; Holanda et al., 2021; Yurong et al., 2021). These feed additives bind toxins in the gastrointestinal tract, reducing their bioavailability and limiting their harmful effects on animal organisms (Papatsiros et al., 2024). As a result, the use of adsorbents can contribute to improved feed utilization, enhanced animal performance, and reduced economic losses in animal production systems (Nikolov et al., 2024). In addition, adsorbents may improve digestive efficiency and support the more effective use of nutrients (Faustov et al., 2022). The most commonly used mycotoxin adsorbents include bentonite clays, silicates, and zeolites (Aoyanagi et al., 2023; Vila-Donat et al., 2018). Bentonite, in particular, is capable of binding a wide range of organic and inorganic compounds within the gastrointestinal tract while generally not affecting mineral metabolism (Horky et al., 2022; Isloor et al., 2014).

Several studies have demonstrated the effectiveness of specific feed additives in reducing the effects of mycotoxicosis in pigs. For example, the feed additive "Harufix+" has been reported to be biologically safe and to positively influence body weight gain in pigs exposed to mycotoxins (Aoyanagi et al., 2020). However, most studies evaluating mycotoxin adsorbents focus primarily on well-established commercial products with a long history of application. Comparatively little attention has been paid to sorbents produced in Ukraine, and comparative analyses between domestic and imported products are largely absent from the available literature (Solodka et al., 2021). It is possible that certain locally produced adsorbents may demonstrate comparable or even superior performance under specific feeding conditions and could represent a more economically viable option for individual farms.

Therefore, the aim of this growth performance trial was to conduct a comparative evaluation of the effectiveness of mycotoxin adsorbents of Ukrainian and foreign origin in pig feeding based on key productivity indicators.

Materials and methods

Study design and animals

The study was conducted at LLC "Agroprime Holding" (Bolhrad district, Karakurt village, Ukraine). A growth performance trial was performed using four groups of pigs, each consisting of 13 animals. The pigs were hybrids of the Large White and Landrace breeds and were approximately equal six months of age at the beginning of the experiment. The total initial live weight of animals included in the study was 6,297 kg.

Animals were maintained according to standard farm production conditions and received a common basal diet formulated for pigs of the corresponding production stage. The experimental period lasted 26 days.

Diet and experimental treatments

All groups received the same basal diet consisting of wheat, barley, maize, sunflower meal, dietary fiber, wheat bran, soybean meal, Porker BMWD premix, sunflower oil, and UT-Tox. Three experimental groups were fed with the basal diet supplemented with one of the tested mycotoxin adsorbents: Harufix, ProActivo, or Clinotoxil. The additives were incorporated into the feed at a dosage of 2 kg per 1 ton of feed. During the experimental period, each group consumed approximately 1 ton of feed. The detailed description of study groups is presented in Table 1.

Growth performance assessment

Animal productivity was evaluated by measuring body weight before and after the experimental feeding period. For each group, the number of animals, total group body weight, and average body

Table 1 – Composition of the basal diet and main components of the sorbents evaluated in the pig growth performance trial

Diet and feed additives	Composition
Basal diet, Control group	wheat, barley, maize, sunflower meal, dietary fiber, wheat bran, soybean meal, Porker BMWD premix, sunflower oil, and UT-Tox
Harufix, H-exp group	Aluminosilicates, kaolinites, cell wall components (mannan oligosaccharides and β-glucan) derived from inactivated yeast cells Saccharomyces cerevisiae. (HaruPharm, Austria).
ProActivo, P-exp group	Bacteria Bacillus subtilis (strain AX20) and Bacillus licheniformis (strain EA22), the enzymes including amylase, protease, cellulase, β-glucanase, and xylanase. (Kronos Agro, Ukraine).
Clinotoxil, C-exp group	Aluminosilicates, attapulgite, fumaric acid, citric acid, and succinic acid. (LLC "ZVK Profit", Ukraine).

Table 2 – Body weight and average daily gain evaluated in the pig growth performance trial comparing groups receiving different dietary sorbents (M ± m, n = 54)

Parameters	Control	H-exp	P-exp	C-exp
Number of pigs before treatment	13	13	13	13
Weight before treatment, kg	1580	1578	1567	1572
Mean weight of one animal before treatment, kg	121.54 ± 0.18	121.38 ± 0.24	120.74 ± 0.21	120.92 ± 0.24
± compared to control	-	-0.16	-0.8	-0.62
Number of pigs after treatment	13	13	13	13
Weight after treatment, kg	1832	1857	2019	2044
Mean weight of one animal after treatment, kg	140.92 ± 0.2	142.85 ± 0.17***	155.31 ± 0.17***	157.23 ± 0.16***
± compared to control	-	+1.93	+14.39	+16.31
Absolute weight gain, kg	252 ± 0.27	279 ± 0.25***	422 ± 0.36***	472 ± 0.24***
± compared to control	-	+27	+170	+220
Relative gain for group, %	14.77 ± 0.24	16.24 ± 0.22***	23.54 ± 0.13***	26.11 ± 0.23***
± compared to control	-	+1.47	+8.77	+11.34
Average daily gain per group, kg	9.69 ± 1.26	10.73 ± 0.99	16.23 ± 0.8***	18.15 ± 0.8***
± compared to control	-	+1.04	+6.54	+8.46

Note: significant differences as compared to control: *** – P <0.001.

weight per animal were recorded at the beginning and at the end of the trial.

Based on these measurements, the following productivity indicators were calculated: absolute body weight gain, relative weight gain within the group, and average daily gain. Differences between experimental groups and the control group were also determined.

Economic evaluation

An economic evaluation of the use of mycotoxin adsorbents was conducted based on production data obtained during the experiment and the farm's internal economic parameters. The analysis included calculation of the market price of pork per kilogram, total production costs, cost of body weight gain per kilogram, net profit per group, net profit per animal, and overall profitability of production. Differences between experimental and control groups were also estimated. These calculations were intended to provide an approximate assessment of the potential economic effect of the tested feed additives under the specific production conditions of the farm.

Ethical considerations

All procedures involving animals were conducted in accordance with the Ukrainian Law "On Protection of Animals from Cruel Treatment" and the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Council of Europe, 1986; European Commission, 2002). Animal management complied with national standards: "Pigs. Zootechnical Requirements for Keeping Breeding Young Animals" (DSTU 4719:2007) and "Concentrated Feed for Pigs. Technical Specifications" (DSTU 4508:2005).

Statistical analysis

Statistical analysis was performed using Microsoft Excel. Descriptive statistics were calculated for productivity indicators. Differences between individual experimental groups and the control group were evaluated using Student's t-test, while overall differences among the four groups were assessed using one-way analysis of variance (ANOVA). Statistical significance was considered at $P < 0.05$.

Results

The effectiveness of the tested mycotoxin adsorbents was evaluated by comparing growth performance, feed utilization, and estimated economic indicators between the control and absorbent-exposed groups during the 26-day feeding period.

Growth performance of pigs

The growth performance indicators suggested that the tested sorbents differed in their effects. At the beginning of the treatment, the average body weight of pigs was similar among groups (120.74–121.54 kg). Thus, initial distribution of animals before treatment was acceptable for further comparison (Table 2).

By the end of the experimental period, pigs receiving sorbent-supplemented diets demonstrated higher body weight compared with the control group. The mean body weight per animal reached 142.85 ± 0.17 kg in the H-exp group, 155.31 ± 0.17 kg in the P-exp group, and 157.23 ± 0.16 kg in the C-exp group, compared with 140.92 ± 0.20 kg in the control group ($P < 0.001$). A similar trend was observed for growth indicators. Absolute body weight gain amounted to 252 ± 0.27 kg in the control group, while higher values

Table 3 – Feed consumption in the pig growth performance trial comparing groups receiving different dietary sorbents (M±m, n = 54)

Parameters	Controls	H-exp	P-exp	C-exp
Daily feed ration per group, kg	38.46	38.46	38.46	38.46
Daily feed ration per animal, kg	2.95	2.95	2.95	2.95
Cost of 1 kg of feed, UAH	9.3	9.65	9.63	9,67
Cost of sorbent, UAH	-	348	330	370
Feed cost per group, UAH	9300	9650	9630	9670
Feed conversion ratio	3.96	3.46	2.28	2.21
± compared to control	-	-0.5	-1.68	-1.75

Table 4 – The estimated economic outcomes of sorbent use in the pig growth performance trial comparing groups receiving different dietary sorbents (M ± m, n = 54)

Parameters	Controls	H-exp	P-exp	C-exp
Sale price per 1 kg, UAH	120	120	120	120
Production costs, UAH	248	248	248	248
Cost per 1 kg of weight gain, UAH	37.80	35.47	23.40	21.01
± compared to control	-	-2.33	-14.40	-16.79
Net profit per group, UAH	20692	23582	40762	46722
± compared to control	-	+2890	+20070	+26030
Net profit per animal, UAH	1591	1814	3135	3594
± compared to control	-	+223	+1544	+2003
Profitability per group, %	68.42	70.43	80.49	82.48
± compared to control	-	+2.01	+12.06	+14.06

were recorded in the experimental groups: 279 ± 0.25 kg in the H-exp group, 422 ± 0.36 kg in the P-exp group, and 472 ± 0.24 kg in the P-exp group. The highest increases in weight gain and average daily gain were observed in the P-exp and C-exp groups.

Feed conversion

Feed consumption was identical across groups and averaged 2.95 kg per animal per day (Table 3). However, the feed conversion ratio differed considerably between treatments. The control group showed a feed conversion ratio of 3.96, whereas lower values were observed in all experimental groups: 3.46 in the H-exp group, 2.28 in the P-exp group, and 2.21 in the C-exp group. The most pronounced improvements in feed efficiency were therefore associated with P-exp and C-exp supplementation.

Economic indicators

The estimated economic outcomes of sorbent use were analyzed to assess the profitability of its application (Table 4). The cost of producing 1 kg of body weight gain was lower in the all experimental groups compared to the control group, with the largest reductions observed in the P-exp and C-exp groups (23.40 and 21.01 UAH/kg, respectively, compared with 37.80 UAH/kg in the control).

These changes were reflected in higher calculated profitability indicators. Net profit per group increased from 20.692 UAH in the control group to 23.582 UAH, 40.762 UAH, and 46.722 UAH in the H-exp, P-exp, and C-exp groups, respectively. The highest profitability values were observed in the groups supplemented with receiving P-exp and C-exp.

Discussion

This growth performance trial aimed to evaluate the effects of several mycotoxin sorbents of domestic and foreign origin on productivity indicators of pigs under commercial production conditions. After the 26-day feeding period, pigs receiving diets supplemented with sorbents demonstrated higher growth performance and improved feed utilization compared with animals in the control group. Under the production conditions of the studied farm, these changes were accompanied by lower calculated costs of weight gain and higher estimated profitability of pig production.

The results of the present study indicate a generally positive effect of mycotoxin sorbents on metabolic processes and the growth intensity of pigs. However, the magnitude of this effect differed between the tested additives. The most pronounced beneficial effects across the analyzed productivity indicators were observed in the C-exp experimental group receiving the sorbent "Clinotoxil". This product contains aluminosilicates, attapulgite, fumaric acid, citric acid, and succinic acid. The observed effects may be associated with the combined action of these components, including the influence of organic acids on intestinal barrier functioning and the composition of the intestinal microbiota (Masiuk & Nedzvetsky, 2025). In addition, the relatively low feed conversion ratios observed in the experimental groups indicate a more efficient utilization of feed for pig growth.

The calculated cost of 1 kg of weight gain ranged from 37 to 21 UAH among the experimental groups, which can be considered economically favorable for pig production and reflects the efficiency of the feeding strategy used in the study. The lowest cost of weight gain was observed in groups P-exp and C-exp receiving the sorbents "ProActivo" and "Clinotoxil". Similarly, the profitability analysis demonstrated noticeable differences between the experimental groups. Group 1 showed only a slight increase in profitability (2.93%), whereas groups 2 and 3 demonstrated substantially higher values (17.64% and 20.54%, respectively). Thus, although both the control group and experimental group 1 demonstrated acceptable profitability levels, the use of sorbents in groups 2 and 3 was associated with more favorable economic outcomes under the studied production conditions.

Comparable effects of sorbent supplementation have also been reported in previous studies. According to Sanzhara et al. (2022), the inclusion of the sorbent "Clinotoxil" in the diet of Large White pigs aged 2–7 months (1 kg per ton of feed mixture under ad libitum feeding conditions) increased production output by 11.5% (Sanzhara et al., 2022). In the present study, the increase in production indicators reached 46.6%. Such differences may be explained by variations in experimental conditions, including differences in animal age, feeding strategies, and genetic background of the pigs used in the experiments. These factors may influence the response of animals to feed additives and therefore should be considered in future studies evaluating the effectiveness of sorbents in different breeds and hybrids of pigs.

Similar results have also been described for the sorbent "Harufix". In a study by Reshetnichenko and Bezalychna (2022), supplementation of pig diets with "Harufix" at a level of 2 kg per ton of compound feed in 45-day-old Large White pigs resulted in additional production valued at 1,339 UAH for a group of 10 animals (Reshetnichenko & Bezalychna, 2022). In the present study, the calculated additional production reached approximately 2.230 UAH for a comparable group size. As in the previous comparison, these differences may be related to variations in age, breed characteristics, and feeding conditions between the studies.

An analysis of the tested sorbents composition in relation to the basal diet used in the present study suggests that the differences in observed efficiency may also be related to their functional components. The sorbent "Harufix" contains prebiotic compounds such as mannan oligosaccharides and β-glucans, which are primarily associated with immune support rather than with direct improvement of nutrient utilization in diets with high fiber content. In contrast, the sorbents "ProActivo" and "Clinotoxil"

contain components that may contribute more directly to improved digestion and nutrient absorption. These include digestive enzymes (amylase and protease), probiotic microorganisms (*Bacillus subtilis* and *Bacillus licheniformis*), and organic acids (fumaric, citric, and succinic acids), which are known to stimulate appetite, support intestinal function, and improve feed utilization. Furthermore, short chain fatty acids confirmed as a protector of intestinal barrier integrity and immunomodulator (Masiuk et al., 2024). Together, aforementioned mechanisms may partly explain the higher productivity indicators observed in the corresponding experimental groups.

Conclusions

Taken together, the results of the present study indicate that the tested mycotoxin sorbents differed with respect to growth performance, feed utilization, and calculated economic indicators in pigs. The observed variation in beneficial effects may be related to differences in the composition of the tested supplements, particularly the presence of specific bioactive components that may influence nutrient absorption, intestinal function, and detoxification processes.

At the same time, several limitations of the study should be considered. The experiment was conducted over a relatively short feeding period and under the production conditions of a single farm, which may limit the generalizability of the results. In addition, the study design does not allow the individual contribution of specific components of the sorbents to be determined. Further research is therefore required to evaluate the mechanisms of action of individual sorbent components and to assess their effectiveness under different feeding conditions, production systems, and pig genotypes.

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Author Contributions

K.S.V. – collection and processing of research materials; preparation of 50% of the manuscript.

T.L.O. – development of the study concept and structure; analysis and verification of experimental results; preparation of 50% of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

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