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Zinc intake and Fecal Excretion in Pigs: Examining the Relationship between Dietary Content and Absorption

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Abstract
Pigs that consume too much Zinc (Zn) excrete it through their faeces, which is bad for the environment. Laying pig manure out with elevated Zn content can reduce soil fertility and help microbes in the soil develop genes for resistance to antibiotics. In this study, WP (weaned pigs) will be examined to determine the relationship among day Zn Consumption and excretion. We will also assess how dietary Zn concentration affects Zn excretion across a range of weight categories. The technique of connection among everyday Zn excretion and Zn consumption was created using a meta-regression study of 10 published investigations with pigs that were weaned over the initial 6 weeks PW. A framework for Zn Consumption at particular amounts over the initial two weeks PW was created using experimental information from 179 newly WP given six different nutritional Zn concentrations. Using both models to determine daily Zn outflow for various food levels of Zn throughout the initial two weeks PW. The use of an improved published model to determine total Zn outflow via withdrawing to slaughter under various dietary Zn Consumption status. Depending of the composition of additional Zn, Zn consumption increased Zn excretion linearly. During the initial two weeks of PW, daily Zn outflow at 3,000 ppm dietary Zn intended to be 8.0 g/pig. There was a 94% and 36% decrease in daily Zn excretion when dietary Zn level was reduced to 160 ppm or 1,500 ppm, respectively. Under particular dietary Zn concentration status, total Zn output from suckling until slaughter was 31.0 g/pig. Zn excretion was significantly reduced by adjusting dietary Zn concentration across all weight categories. The biggest reduction was attained by lowering the dietary Zn content for pigs weighing 32 to 118 kg from 120 ppm to 60 ppm. According to the study, dietary Zn concentration can be changed to dramatically lower the amount of Zn excreted by pigs. The most significant reduction can be made by lowering the Zn level of the diet for pigs weighing 30 to 110 kg. These results have implications for reducing the environmental harm caused by Zn outflow and should be taken into account when creating plans to control the amount of Zn in pig diets.

Keywords: Zinc (Zn), excretion, dietary, antibiotics, weaned pigs (WP).

Introduction

Pigs require Zn, a vital substance, for an array of physiological processes, much like other mammals do. It is necessary for growth, immune response, enzyme activity, and reproduction. Optimal Zn levels in pigs' diets are essential to preserving their greatest health and performance. However, excessive Zn Consumption might result in it being expelled through faeces, which might have negative effects on the ecosystem. When used as fertilizer for crops, pig a slurry that contains elevated Zn concentrations, can encourage the establishment of antibiotic resistance genes in soil bacteria. Furthermore, the elevated Zn concentrations may negatively impact soil fertility, making sustainable agriculture more challenging [1]. Understanding the relationship between dietary Zn consumption and faecal

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outflow in pigs is essential for managing nutritious Zn levels and reducing environmental issues. By investigating the variables that govern it, such as the feed mix and pig weight categories, it is possible to establish policies to lessen Zn excretion and the associated environmental issues. For an animal to be healthy and happy, the number of nutrients present in the food, especially nutrients such Zn, is essential. Understanding the relationship between food ingredients and the absorption of essential minerals is particularly crucial for the aim of improving nutritional strategies and sustaining optimal animal performance [2]. Animals need Zn, an essential mineral, for a variety of physiological processes include enzyme functioning, development, immunity, and reproduction. The content of Zn in a diet and the absence of additional nutritional elements are two factors that can affect how well Zn is absorbed from food. The interactions that occur between dietary components and the gastrointestinal system have an impact on the bioavailability of Zn, which is the portion of ingested Zn that gets absorbed and utilized by the body [3]. Zn absorption can be impacted by elements like the source and type of Zn, in addition to the presence of additional nutrients in the diet like phytate, fibre, and other minerals. Diets that maximise Zn bioavailability must take into account the mechanisms and variables affecting Zn absorption [4]. It is possible to establish strategies that improve Zn utilisation and minimise Zn excretion, hence minimising the potential environmental impact, by looking at the link among dietary content and Zn absorption [5].

The purpose of the research is to look into the connection between WP' daily Zn consumption and faecal excretion. The goal of the study is to create equations that quantify the effect of Zn consumption on Zn excretion through the review of existing research and the execution of fresh tests. Additionally, the study intends to assess how dietary Zn amount and pig categories of weight affect Zn excretion patterns. Study [6] evaluated the effects of different commercial Zn supplementation methods on weaners' Zn balance, health and growth performance under field conditions. Additionally, They looked at the effectiveness of using nanoscale Zn oxide (n-ZnO) at an appropriate dosage (150 mg kg1) to reduce diarrhea incidences. The study [7] analyzed the efficacy of enzymes treated cerevisiae (HY40) as an alternative to pharmaceutical Zn oxide (ZnO) and see if there were any extra advantages to giving nursery pigs both HY40 and ZnO after weaning. The study [8] sought to ascertain the oral safety and preparation features of chitosan-Zn chelate (CS-Zn), as well as its bioavailability in WP. Seven feeding regimens were given to 210 crossbred WP (Duroc x Landrace x Large White), each weighing an average of 6.30 kg. These treatments included a Zn-unsupplemented control diet and a 2x3 factorial design with two Zn sources (CS-Zn and ZnSO4) and three amounts of additional Zn. Study [9] compared the two types of zn phosphate-based fine particles to see how they affected growth efficiency, microbiota in the intestines, antioxidant levels, and intestine. A total of 100 newborn pigs were separated into ten equal groups, each receiving the base diet and supplements containing 500, 1000, or 2000 mg of Zn per kilogramme of food. The control group received the basic diet. Article [10] determined the impact of tetrabasic chloride of Zn (TBZC) supplement on the wellbeing of WP, two trials were carried out. To enhance growth efficiency and reduce Zn outflow in WP,

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the experiments sought to identify the ideal supplemental levels of TBZC and explore whether dietary TBZC may substitute therapeutic amounts of diet Zn oxide (ZnO). Weaning pigs (WP), food digestibility, growth performance, faecal score and toxic gas emission were evaluated in the study [11] discussed about the effects of adding probiotics complexes in meals with high and low amounts of Zn oxide (ZnO). Study [12], examined the WP' development, Zn status, intestinal architecture, microbiota population, and immunological response by feeding Zn oxide nanoparticles. 150 WP were divided into five food groups at random, with a mean weight of 9.37 0.48 kg. Four groups received supplementation with nano-ZnOs at doses of 150, 300, or 450 mg kg-1 or with 3000 mg kg-1 of ZnO as part of the treatments. The article [13] looked at how Zn-HMTB affected cadmium consumption and Cd-induced cytotoxicity in piglets' small intestines. The four dietary treatment groups included the basal diet, meals containing 30 mg/kg Cd from CdCl2, and diets containing 0, 100, or 200 mg/kg Zn from Zn-HMTB. Twenty-four piglets (Landrace Large White, weighing 13.22 0.58 kg) were randomly assigned to each group. The trial lasted 27 days, at which time each piglet's ultimate body weight and feed consumption were noted. Article [14] examined the mechanisms governing iron and Zn homeostasis as well as their interactions at the levels of intestinal absorption and tissue mobilization in the context of Zn status. According to the data, the Zn-DMT1/FPN1 axis was a key factor in the alterations in iron homeostasis brought on by Zn deficiency, and it also aids in understanding the mechanism of interactions between iron and Zn. The purpose of the study [15] was to determine the impact of Zn in aspartic acid oxalate on pig development, nutrient digestion, blood profiles, faecal microbial composition, and faecal gas emission. The investigation aimed to evaluate the impact of Zn-ASP chelate upon the growth efficiency, nutrient digestion, blood profiles, microbial composition of the faeces, and faecal gas emission in developing pigs. The study [16] compared the productive capacity of grower-finisher pigs given hydroxychloride mineral to sulphates, With smaller amounts of Zn, or Zn, and copper (Cu), respectively, than those required by EU standards. The trace mineral sources' chemical characteristics served as the foundation for the idea. To test the idea, the study included an initial vitro assay and a follow-up in vivo investigation.

The goal [17] was to examine the effects of various diets containing various amounts of copper and Zn additions on the growth efficiency, antioxidant performance, immunological function, and faecal metal excretion of piglets and developing pigs. 2000 pigs were used in the trial for the study, divided into early nursery, late nursery, and grower stages. The goal of the study [18] was to determine how produced Zn oxide nanoparticles (ZnO NPs) behave in the simulated physiological environment of the chicken intestines and to evaluate the effects of various dietary ZnO NP levels on Zn uptake, cells shipment, bone quality, mineralization, which is and antioxidant status in broiler chickens. To support green chemistry and precise animal nutrition, the study emphasizes the safer and more environmentally friendly method for synthesising ZnO NPs to be utilized as an animal feed additive. The purpose of the article [19] was to evaluate the effects on development and gut microbiota composition by replacing supra-nutritional doses another oxide of Zn in pig diets with a mixture of protective aromatic

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substances, including the chemical benzoic acid . Piglets were divided into two groups: those getting the safeguarded aromatic compound blend in the experimental group and those receiving a control group. The trial was conducted on four different farms. The study's [20] goal was to determine how Zn oxide nanoparticles or Zn bound with glycine affected WP' growth performance, faecal scores, nutritional digestibility, Zn utilization, blood profiles, and faecal concentrations of Lactobacillus and Escherichia coli. The goal of the study was to ascertain whether Zn may be a suitable replacement for medical Zn oxide.

The purpose of the research is to look into the connection between WP' daily Zn consumption and faecal excretion. The goal of the study is to create equations that quantify the effect of Zn consumption on Zn excretion through the review of existing research and the execution of fresh tests. Additionally, the study intends to assess how dietary Zn amount and pig categories of weight affect Zn excretion patterns.

Materials and Methods

Analysis of meta-regression for WP of Zn Consumption and Zn excretion

A thorough information was carried out in February 2022 using the information given to compile published information on the daily consumption and elimination of Zn, or Zn, in pigs in the first six weeks post-weaning (PW). Ten pertinent papers were found, and the information from these studies was utilized to build response models that could forecast the amount of Zn that WP would excrete. The pigs' initial weight at birth (BW) was 7.1 kg on average, and the median age after weaning was 22.1 days. The ten studies that were examined utilized various Zn sources that were organized into categories for ease of use. The sources were divided into inorganic (I), organically (O), and inherent categories. It is significant to note that the presented information does not contain particular findings and details of the reactions to models that predict Zn elimination in WP. Only the technique and features of the studies that were used in the analysis are described in the material.

Data from experiments: daily Zn consumption and dietary Zn concentration

The average daily Consumption of Zn over the first two weeks post-weaning was calculated using information collected in a Zn dose-effect study in WP. The presented information does not, however, include certain information about the projected daily average Zn Consumption or the outcomes of the dose-response experiment. WP were separated into groups and given one of the six nutritional Zn concentrations in the Zn dose dependence experiment. According to measurements, the Zn contents in the meals were 155, 492, 1,024, 1,604, 2,056, and 2,419 parts per million (ppm). These particular Zn concentrations were added to the pigs' diets, and their Zn consumption was then tracked and examined. The daily Zn Consumption in the first two weeks of post-weaning for three distinct dietary Zn concentrations was calculated using the results of the Zn dose-response experiment. The present legal limitation is 160 ppm, and these three concentrations were chosen expressly to approximate these limits. The predicted daily Zn consumption was utilized to compute the daily Zn excretion in a meta-analysis's linear regression analysis. However, the presented material does not include any additional information regarding the precise findings or results of the analysis.

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Zn excretion and its relationship to dietary Zn in animals from suckling to slaughter

The study probably looked at the impact of the Consumption of Zn in pigs from weaning to slaughter. It's likely that various food Zn amounts or sources were examined to see how they affected the amount of Zn the pigs excreted throughout this time. The study may have analyzed impacts of Zn levels of dietary on Zn excretion patterns during the growth and finishing phases of the pigs' growth up until slaughter weight. The presented information does not, however, include any specifics on the investigation's findings or conclusions. In three different status, Zn output from the suckling stage (6 kg) to the butchering location (108 kg) was calculated using the revised model, which was based on the prior research. The former practice for dietary Zn concentration in pig diets is represented by status 'a', which may have been based on historical data or widespread industry standards. The suggested dietary Zn amounts in Status 'b' are based on data from experiments, which raises the possibility of changing or improving the current procedure. Status 'c' is in line with the established rules since it matches the recommended daily Zn contents as defined by the most recent EU legislation. The presented information does not include the precise facts and computations' outcomes, together with any variations or ramifications across the situations. Table 1 shows the dietary Zn content (ppm) for each of the statuses (a, b, and c).

Table 1: Dietary Zn content (ppm) for each of the situations (a, b, and c)

	Status		
Kg	**a**	**b**	**c**
7-10	2,700	1,500	160
10-30	160	100	160
30-110	160	100	160

Statistical analysis

The study's results are best described as back-transformed using least-squares averages with a confidence interval of 95%. Results with a p-value of less than or equal to 0.05 were regarded as statistically significant, according to a significance level of $P \leq 0.05$. A statistical tendency was also considered present when the p-value fell between 0.05 and 0.10, or between these limits. To evaluate the relevance or trend of the study's findings, these cut-offs were employed.

Meta-regression analysis

The interquartile range (IQR) approach was used to find two outliers and remove them from the analysis. The link between Zn consumption and excretion was studied using a mixed linear regression model. The weaning age and the post-weaning sample period weren't included in the model due to the small number of observations. Instead, the relationship among Zn Consumption was included in the model. The study took into account the effects of zinc intake and zinc source on zinc excretion by treating them as random variables in the model. This method examined possible diversity between and within studies as well as the influence of these characteristics.

Experimental data

A generalized linear framework (GLM) was used to investigate the impact of nutritional Zn concentration on daily Zn consumption. The GLM made use of a Gamma error distributions and included the random impact of a block. In R, a popular statistical analysis computer language, Q-Q maps and residual charts were evaluated to confirm the statistical significance of the data. These graphs were used to evaluate whether the GLM residuals adhered to a standard distribution, which corresponds to a key model presumption. The reliability of the GLM results and the suitability of the Gamma error distributions for the analysis were both confirmed by the review of Q-Q graphs and residual plots.

Results

Zn excretion based on Zn Consumption

WP excretion of Zn rose linearly as Zn Consumption increased P< 0.01, shown in Figure 1. Regarding Zn excretion, there was no evidence of an interaction between the source of Zn (I, O, or N) and Zn Consumption (P = 0.97). Furthermore, the Zn source had no additive effect (P = 0.60). Table 2 displays the standard errors, parameter estimates, estimated covariance components, and root mean square error for the two models.

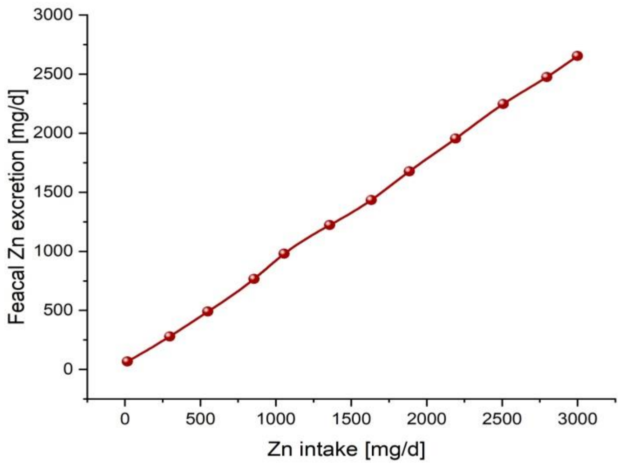

Figure 1: The daily Zn Consumption predicts daily faecal Zn excretion

Zn intake, Zn excretion, and dietary Zn content

The correlation of the mean daily intake and nutritional zinc concentration in the initial two weeks following weaning is shown in Figure 2 of the study. In accordance with three different food Zn concentrations, Table 2 provides information on the daily Zn intake and excretion per pig. According to the findings, decreasing the average daily zinc level in 2,500 ppm to 1,400 ppm or 160 ppm resulted in a 36% and 94% decrease in Zn excretion, respectively.

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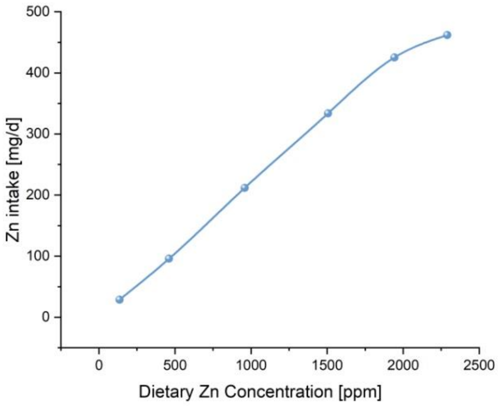

Figure 2: Daily Zn Consumption mean

Table 2: The model's inputs and outputs in the connection between Zn intake and excretion

Variable		**Intercept**	**Zn Consumption**
Parameter Estimates		-	0.85
SE		-	0.03
P-Value		-	<0.01
RMSE		101	
Variance Component	σ_s^2	891	
	σ_b^2		0.01
	$\sigma_{s,b}$		0.84

Zn excretion in pigs

Three different status were used to compute the total amount of Zn output per pig from suckling to slaughter in Table 3. The total amount of Zn excreted in status 'a' was found to be 31 g/pig. In this case, 29% of all Zn excretion happened in pigs weighing 7 to 10 kg, and 59% occurred in animals weighing 30 to 110 kg. The total Zn excretion was estimated to drop by 50% and 26%, respectively. Table 3 shows the estimated pig daily Zn Consumptions and excretions.

Table 3: Estimated pig daily Zn Consumptions and excretions

	Zn Concentration (ppm)		
	2,500	**1,500**	**160**
Zn Consumption			
Mg/d	636	407	41
g/pig	9.0	5.8	0.6
Zn excretion			
Mg/d	539	346	36
g/pig	7.8	5.0	0.6

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Discussion

Pigs excrete dietary Zn that is not absorbed, this can have a negative impact on the environment. Zn buildup in soil can result in hazardous quantities, which are harmful to soil fauna, microbes, and plant growth. The type of soil, quantity of water, pH, and kind of crop all affect how much Zn may be given into the soil without adversely affecting plant growth. Inorganic or organic Zn sources had little effect on the excretion or bioavailability of Zn in WP, according to meta-analyses. Nevertheless, depending on the dietary Zn content, the additional Zn source may affect the daily growth, consumption of feed, and blood Zn levels in WP. The greatest decrease of all Zn excretion can be accomplished by decreasing dietary Zn levels over the 30-110 kg weight period in growing-finishing pigs. The biggest amount of expelled Zn occur from 10 to 110-kg pigs. The largest influence on lowering all Zn excretion during pig production comes from minimizing ingested Zn for this size range. Table 4 shown the Zn Consumption and excretion totals determined for each pig at various weight intervals.

Table 4: Zn Consumption and excretion totals determined for each pig at various weight intervals

		Status		
	kg	**a**	**b**	**c**
Zn Consumption, g/pig	**7-10**	9.0	5.0	0.8
	10-30	4.9	3.0	4.9
	30-110	20.0	11.0	20.0
	Total	34.1	18.5	25.9
Zn excretion, g/pig	**7-10**	8.9	5.0	0.9
	10-30	4.6	3.0	4.3
	30-110	18.7	8.7	18.7
	Total	31.4	16.0	23.0

Conclusions

The study discovered that decreasing the daily zinc (Zn) levels among 7–10 kg pigs resulted in a considerable reduction in Zn outflow per pig, with 94% at 160 ppm and 36% at 1,500 ppm. In contrast to 30-110kg pigs, the effect of food zinc consumption on overall Zn outflow from suckling to slaughter was smaller in 7-10kg pigs. The total amount of Zn output per pig was calculated to be 24g based on the restrictions now in effect in the European Union. Zn excretion may be decreased to 17g each pig by feeding meals with quantities of zinc that match recommended needs. Pigs excrete Zn from their feed that is not ingested, which may harm the ecosystem. Zn accumulation in soil can lead to dangerous levels that are detrimental to soil life, microorganisms, and plant growth. The amount of Zn that can be added to a soil without negatively influencing plant growth depends on the kind of soil, the amount of water, the pH, and the type of crop. Future studies in this area may help to develop a more thorough understanding of the connection between dietary Zn Consumption and pigs' Zn metabolism, resulting in more effective ways to use Zn, less negative effects on the environment, and greater pig well-being and efficiency.

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