Literature Review: Zinc's Usage in Current Feeding Practices and Impact on Microbiome of Animals

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Abstract

Trace metals such as iron, manganese, copper, and zinc play an important role in the regulation of development and growth in livestock animals. This review seeks to examine the methods and impacts that the trace mineral zinc has on livestock animals and their corresponding gut microbiota.

The gut hosts trillions of microorganisms that regulate the metabolism and transport of micronutrients within a living organism's body. Through absorption of food sources, trace metals can modulate the gut microbiome, so it is important to understand the mechanics and processes involved in the metabolism and bio consumption of the gut when taking in trace minerals (in particular, zinc).

Current Feeding Practices in Swine, Bovine, Poultry, and Aqua Culture

After birth, piglets are especially susceptible to a wide variety of infectious diseases and commonly, diarrhea which leads to a high mortality rate after birth if not prevented correctly. It's common that pigs are given a supplement form of zinc, most often in the form of Zinc oxide, ZnO to help combat diarrhea and to ensure that they make it out of their weaning stages healthily.

For example, calves that are fed zinc in the form of forage and basal supplements gained up to 6% more weight than calves in control groups. Calves fed extra forms of zinc have been shown to be able to put on more weight gain, which can speed up the process of maturing into lactating dairy cows and increase production in a shorter frame of time.

Zinc supplementation of lactating dairy cows improves the quality of milk produced, especially in the quality of fatty acids.

Increased dietary zinc levels fed to supplement broiler chickens and other birds have been show to increase the fertility and hatchability of certain breeds. In addition, dietary zinc stimulates the immune system and its response to common illnesses that poultry can catch at a young age and has also been shown to increase structural strength. This can translate into an increased production of eggs and meat and an increased feed efficiency.

Feeding trials that attempted to establish a dietary zinc requirement of *Labeo rohita* lasted for 90 days and consisted of different grading levels of Zn in their diet derived from Zn gluconate. Maximum zn absorption was found to be in fish fed diet with 42 mg/kg Zn, which was shown to have an effect on growth performance and Zn bioavailability in *L. rohita* juveniles.

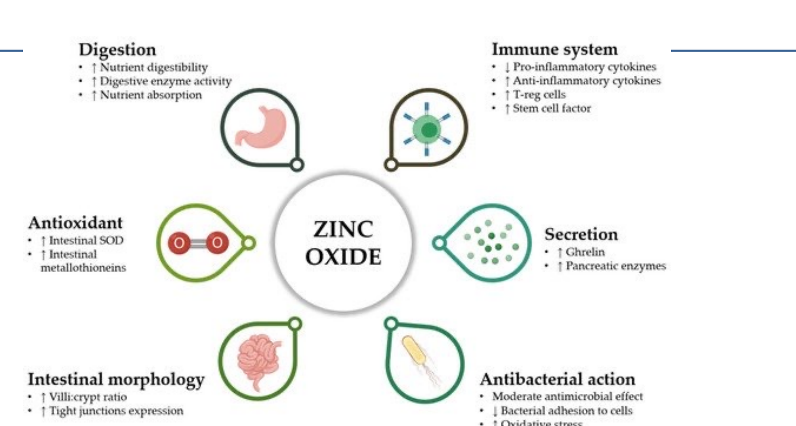


Figure 1. Zinc Oxide's Supplemental Benefits (Bonetti, Tugnoli, et. Al 2021)

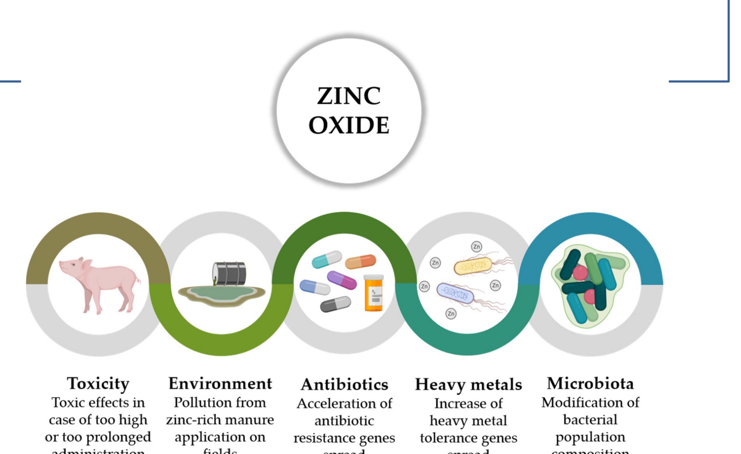


Figure 2. Zinc Oxide's effects (Bonetti, Tugnoli, et. al 2021)

Health Benefits of Zinc in Livestock Species

Feed is commonly supplemented with zinc to prevent a large number of diseases and issues in the immune system for piglets. For example, diarrhea is common in weaned piglets, and one strategy to prevent diarrhea after weaning is to introduce levels of zinc oxide into their diets, leading to a higher growth rate and better feed use.

As a trace element, zinc is vital to a variety of different types of metabolic processes needed for growth in swine, including growth, immunity, development, and reproduction.

Supplementation of zinc can increase growth, ability of detoxification of the gut, and increase endocrine secretion.

There is evidence to suggest that supplementation of dietary zinc has a noticeable positive impact on the quality of bovine milk and cheese derived from it. This is due to the increase in concentration of fatty acids.

Supplementation with zinc can lead to greater hatchability performance, offspring chick performance, and enhanced progeny immune status. Therefore, studying the protective effect of Zn and the improvement that is achieved with increased levels of organic Zn supplementation continues to be a development field of interest for researchers.

Concerns About Surplus Zinc in Livestock Feed

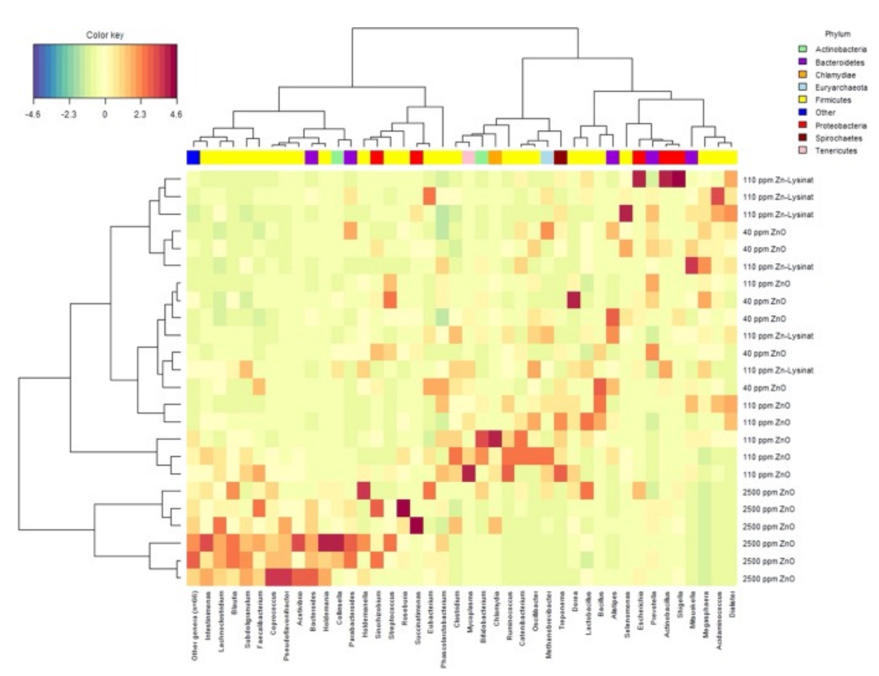
Zinc toxicity can occur with extremely high intakes, and manifestations of symptoms can be seen in a variety of livestock feed if dosing is not appropriate to the level that pharmacological doses warrant (Fosmire 1990).

Zinc toxicosis leads to different effects in a animals outlined above. In general, a common effect among livestock animals is that excess zinc caused by toxicosis leads to weight loss and a loss of appetite.

Zinc toxicosis in ruminants can result in a loss of appetite, diarrhea with dehydration, jaundice, decreased milk production, and lethargy. Chronic overdosing can lead to a degradation of the liver, kidneys, and other vital organs.

A journal article from a 1966 study that seeked to determine the zinc toxicity threshold in cattle noted that zinc levels of 0.9 gm per kg of diet provided caused reduced gains in body weight and lowered feed efficiency (Ott 1996). In addition, zinc levels of 1.7 gm. Per kg of diet caused reduced feed consumption and depraved appetite. Effects were seen to be more severe in steers than heifers (Ott).

To avoid zinc toxicity, measures should be taken to always ensure that zinc is dosed to the appropriate weight, at the correct intervals, and with precision and consistency in supplementation.



Heatmap showing the relative abundance of the most prevalent identified bacterial genera and related phyla in colon digesta of piglets ($n = 6$/group) fed diets with added zinc oxide at 40 ppm (40ZnO), 110 ppm (110ZnO), 2500 ppm (2500ZnO), or 110 ppm Zn-Lysinate (110ZnLys). (Pieper, Dadi, et. Al 2020)

Groups	Richness indices		Diversity indices	
	Observed species	Chao1	PD whole tree	Shannon
ILEUM				
Control ($n = 4$)	1713.50 ± 98.66	2905.81 ± 209.69	87.94 ± 3.27	7.26 ± 0.29
Antibiotics ($n = 4$)	1800.20 ± 140.37	3521.36 ± 258.69	100.65 ± 5.46	6.82 ± 0.44
zinc oxide (ZnO) ($n = 4$)	1733.30 ± 115.41	3277.46 ± 150.33	96.74 ± 6.51	6.83 ± 0.42
P.value (Antibiotics vs. Control)	0.42	**0.02**	**0.01**	0.19
P.value (ZnO vs. Control)	0.83	**0.03**	**0.04**	0.2
P.value (ZnO vs. Antibiotics)	0.55	0.21	0.46	0.96
COLON				
Control ($n = 4$)	2703.35 ± 75.76	4809.94 ± 371.91	137.94 ± 3.96	8.91 ± 0.21
Antibiotics ($n = 4$)	2452.23 ± 102.21	4337.07 ± 252.35	130.25 ± 4.76	8.69 ± 0.12
ZnO ($n = 3$)	2496.43 ± 28.61	4586.71 ± 241.31	131.94 ± 0.77	8.54 ± 0.19
P.value (Antibiotics vs Control)	**0.01**	**0.02**	**0.04**	0.16
P.value (ZnO vs. Control)	**0.01**	**0.04**	**0.01**	0.08
P.value (ZnO vs. Antibiotics)	0.56	0.28	0.63	0.25

Significant p-values (< 0.05) are bolded.

Chart 1. Richness and Diversity Indices Estimation of Intestinal Microbiota with Varying Zinc Supplementation (Yu, Zhu, Chen, et. Al 2017)

Zinc's Impact on the Gut Microbiome

There exists an abundance of current studies on the supplemental zinc's impact on the microbiota and gut health in swine.

Piglets are especially susceptible to various diseases because of their incomplete and underdeveloped immune system after birth. Zinc oxide (ZnO) is commonly used as a weaning diet supplement to prevent diarrheal diseases and to encourage rapid immune system development.

A previous study (Oh et. Al, 2021) has shown that groups of weaned piglets supplement with 2500 ppm exhibited improved diarrhea scores and likely had a microbiome more strengthened to prevent diarrhea as a result.

It is not well known how changes in microbial function are impacted by organic zinc sources. However, Zn-Lysinate as an organic zinc source promotes glycan foraging and has a positive impact on the production of metabolites (Pieper 2020).

Consistent supplementation of dietary zinc oxide can change the microbiome of ileum and colon in weaned piglets. In a comparative study examining microbiome performance, Yu et al. (2017) produced results that showed that both ZnO and in-feed antibiotic supplementation significantly increased different types of bacteria in ileal digesta.

Conclusions

Current feeding practices have been established to sustain the well-being of livestock animals, including various different species in swine, bovine, poultry, and aqua culture. Supplementation in the form of zinc often comes with a number of health benefits, though overdosing and chronic over supplementation of zinc can lead to zinc toxicosis and negative side effects. There remains a lot of information that is not well known about the effect of zinc's impact on the gut microbiome and about the effect of surplus zinc in livestock feed.

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