Sulfur is an important element essential for animal growth because it is required for the formation of many sulfur-containing compounds found in essentially all body cells.

Extensive research has been conducted to understand the relationship of sulfur and amino acid metabolism. The intake of inorganic sulfur in swine diets hasn’t received much research interest until recently. The incorporation of dried distillers grains with solubles, which may contain higher levels of sulfur than expected compared to the level of sulfur typically found in corn, into swine diets has raised the question of what the maximum sulfur tolerance level is in swine diets.

The increased sulfur level could serve as a substrate for hydrogen sulfide production by sulfate-reducing bacteria. Previous research has shown that pigs that are forced to consume water with sulfate will suffer initially but can adapt to the increased sulfur intake that persists in the feces. Researchers have reported that increased levels of dietary sulfur increased sulfur-containing odors. Also, increased hydrogen sulfide causes gastrointestinal epithelial damage, which leads to the development of chronic diseases such as colorectal cancer.


In experiment 1, the control diet was formulated with dicalcium phosphate and sulfate-based trace minerals, whereas the low-sulfur diet was formulated with defluorinated phosphate and non-sulfate trace minerals. The diets contained 0.80% calcium, 0.42% available phosphorus, 17.6% protein, 3,250 kcal of metabolizable energy per kilogram and 1.12% standardized ileal digestible lysine. The control diet contained 2.135 mg/kg of water sulfate per kilogram of diet, and the low-sulfur diet contained 1,755 mg/kg of sulfur.

In experiment 2, the control diet was formulated with monoammonium phosphate and sulfate and trace minerals, and the low-sulfur diet was formulated with defluorinated phosphate and non-sulfate trace minerals. The diets contained 0.74% calcium, 0.49% available phosphorus, 21% crude protein, 3,325 kcal of metabolizable energy per kilogram and 1.15% standard ileal digestible lysine. Calcium sulfate was added to the control diet at zero (2.059 mg/kg), 0.625% (4.014 mg/kg), 1.25% (5.066 mg/kg), 2.5% (7.183 mg/kg) and 5% mg/kg (11.399 mg/kg). The dietary calcium and phosphorus levels were increased to 1.54% calcium and 0.83% available phosphorus with the five treatment levels of calcium sulfate.

Experiment 1 utilized 42 pigs weighing 13.8 kg and lasted 24 days. Experiment 2 utilized 63 pigs weighing 13.4 kg and lasted 35 days. Pigs were allotted to individual stainless steel pens with free access to feed and water. Pigs and feeders were weighed at the beginning and the end of each experiment.

At the end of experiment 2, samples were obtained for later analysis, including feces (analyzed for pH, reduced sulfur and ammonia), ileum and colon tissue, ileum mucosal scrapings and intestinal contents.

Table 1 summarizes the performance of pigs in experiment 1, and Table 2 summarizes the performance of pigs in experiment 2. The researchers provided the following interpretations of the results obtained from the two experiments:

- Reduced dietary sulfur by approximately 200 mg/kg had no effect on pig performance in experiment 1.
- The increase in calcium and phosphorus in the calcium sulfate treatment in experiment 2 had no effect on average daily gain (ADG), average daily feed intake (ADF) or gain:feed, indicating that responses to dietary sulfur were not confounded by dietary calcium and phosphorus.
- Even though there was a linear decrease in ADG in experiment 2, the largest depression in ADG was noted in pigs fed the 2.5% and 5% levels of calcium sulfate.
- Pig performance was not markedly affected by up to 10,000 mg/kg of water sulfate per kilogram of diet in experiment 2, which is remarkable considering that 4,000 mg of water sulfate per kilogram of diet is considered toxic in ruminants.
- Table 3 summarizes the fecal composition of pigs fed zero or 5% calcium in experiment 2.

The researchers provided the following interpretations of these results:

- The pigs fed 5% calcium sulfate appeared to have stools that were not as firm as pigs fed no calcium sulfate. Several researchers have reported that the increase in intestinal sulfur is likely not due to a lack of absorption but to the greater sulfate concentration irritating the intestinal mucosal, which causes an accelerated transit of intestinal contents and results in stool looseness or diarrhea.
- Other researchers have reported no evidence of intestinal mucosal damage in pigs that consume drinking water containing 2,650 mg of sulfate per liter of water for 10 days.
- Pigs fed the 5% calcium sulfate diet also had feces with lower pH and a tendency for decreased ammonia compared with pigs fed the 6% calcium sulfate diet.

The researchers indicated that regardless of whether the dietary sulfur from sulfate was absorbed or not, it was not utilized, resulting in increased sulfur in the manure. Also, minimizing manure sulfur could be important for reasons other than odor arising from animal production facilities. A further possible explanation for alterations in ileal inflammatory mediators observed in the intestinal macrophage induced by the high-sulfur diet. In this study, pigs fed the greater amounts of sulfur had decreased sulfate-reducing bacterial populations in the small intestine, but the opposite was noted in the colon and feces.

Total bacterial populations of the colon and fecal samples did not seem to be markedly affected by a change in dietary sulfur. There was an increase in bacterial concentrations in the progression from the small intestine to the colon and, ultimately, in the feces.

The Bottom Line
One of the concerns when feeding dried distillers grains plus solubles to swine found that the ingredient may contain a relatively high amount of sulfur.

This extensive study found that growing pigs are quite tolerant of increased dietary inorganic sulfur relative to growth performance, even though an extremely high dietary sulfur level can alter inflammatory mediators and intestinal bacteria.

Reference