Looking at sulphur and sulphate levels in poultry diets

In its organic form sulphur is an essential element for poultry as it is involved in protein synthesis. However, as with most elements, with elevated intakes from both feed and water there is a potential for toxicity.

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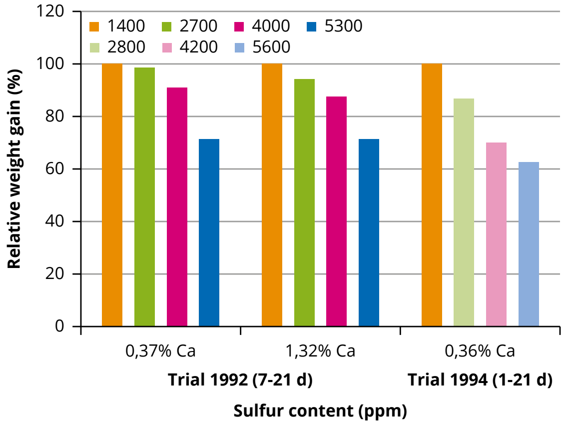
During the early years of dedicated poultry production, feed was based on single cereal and protein source ingredients. Although rarely measured at that time, sulphur (S) content in corn could range from 300 to 4,000ppm. Indeed, S is one of the essential elements for plant development and is required by the corn. Later, with the intensification of crop harvest yields and more rational application of manure to soils, an increase in S deficiency in corn crops was observed. This led to the application of fertilizers to enhance S content in corn. Over the last decade, a significant increase in dietary sulphur content continued to occur in livestock diets with the use of DDGS (essentially, concentrated corn) as a cost-effective ingredient, and the use of trace minerals in the form of sulphate.

Figure 1 - Relative weigth gain (% to control treatment) of broilers fed S-supplemented SBM diets.



Nowadays, most macro and micro ingredients used in poultry diets contain some S, either as organic compounds (methionine and cysteine), sulphates (trace mineral sources, lysine and sulphamethazine) or toxic glucosinolates (present in former canola varieties). Organic S compounds in the form of amino acids or vitamins (thiamine and biotin) are essential nutrients for poultry. Like other vertebrates, birds are not capable of synthesizing these nutrients from inorganic S so they must be supplied by the diet. But according to the NRC recomendations (2005), maximum tolerable levels of S in the diet in poultry are 4,000ppm.

Understanding sulphur toxicity

Sulphur toxicity in poultry is known to induce nonspecific pathological conditions, such as poor growth performance, impaired ash deposition in bones, disturbed ovary function and wet litter issues. The interest in S toxicity came along with the use of sulphamethazine for the control of coccidiosis. Although very effective, the product was seen to be detrimental in overdosing situations that often occurred when applied in drinking water.

Harmful effects attributed to S have been reported at ingestion levels above 3,000ppm. The University of Guelph (Canada) has conducted trials to assess the growth of broilers in response to S intake. With increasing inorganic S content, a linear depression in weight gain was reported as a consequence of reduced feed intake and due to an impaired anion-cation balance *(Figure 1)*.

Impact of S on dEB calculation

In 1981 Pierre Mongin from INRA (France) showed the importance of maintaining a constant electrolyte balance in the diet (dEB). Mongin's original equation included the sulphate present in the diet: $DEBmEq/kg = (Na \times 434.98) + (K \times 255.74) - (Cl \times 282.06) - (SO4 \times 208.29)$.

Over time, the sulphate component in the equation was ignored as it was deemed less metabolically active than Cl- and because dietary SO4- levels were considered to be low. The current equation for calculating dEB only considers two

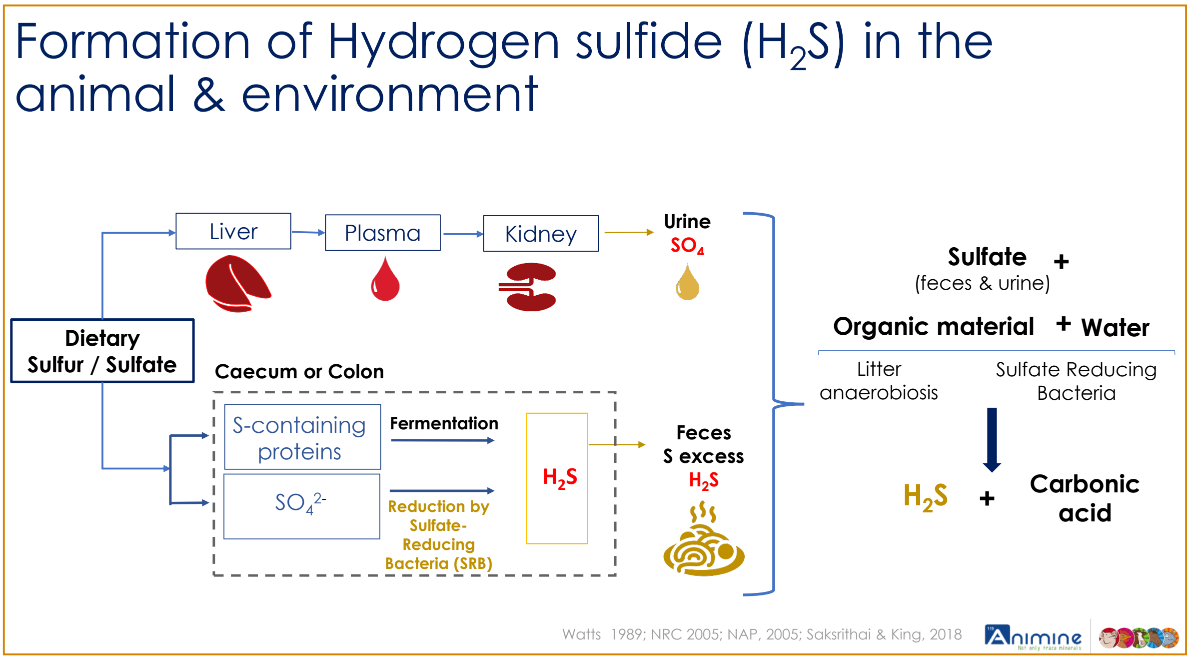


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Figure 2. Sulphur and sulphate transformation in the GIT and the environment.

cations (Na+ and K+) and one anion (Cl-): *dEBmEq/kg = (Na×434.98) + (K×255.74) – (Cl×282.06)*.

Recently, in a feed formulation exercise conducted together with a Dutch research centre, Schotorst, the total S content of a starter corn and SBM-based diet for broilers was increased from 2400 to 3500ppm. Both diets were iso-protein, iso-Met and iso-energetic. SBM inclusion level (22.6%) in the low-S diet was replaced by SBM (11.7%), rapeseed (6.7%), feather meal (3.7%) and hydrolysed porcine intestine (2.04%), all being contributors to S content.

The dEB of each diet was calculated using the two available equations. In the first case (using the current dEB equation), both dEB values were very similar *(see Table 1)*, leading to the assumption that this parameter was good and would not affect bird performance. (NB: for optimum performance a dEB of around 240-250meq/kg is required). When the second equation was applied (Mongin's calculations with sulphates), dEB values not only showed a wider divergence from each other but were also below the reference value for performance.

Other toxic S-related compounds

In poultry operations emissions of toxic gases, such as hydrogen sulphide (H_2S), can influence the prevalence of various diseases. Such emissions also represent an important health risk for workers, particularly during manure-handling processes because of the rapid release of this gas. A study in 2017 reported that H_2S emissions in manure-belt houses are 77% higher than in the old high-rise layer houses. H_2S is the final product of sulphate-reducing bacteria that anaerobically decompose S-containing amino acids and break down sulphates, forming intermediate S compounds that ultimately form H_2S *(Figure 2)*. From human medicine it is known that high concentrations in the gut can adversely affect gut function (increasing inflammation and motility) and microbiota composition.

In poultry production systems, particular attention to H_2S toxicity has been given primarily in relation to respiratory disorders. Inhaled H_2S rapidly enters the blood stream, where it dissociates, binds to haem compounds and is partially metabolized by oxidation to sulphate and excreted in the urine. But excess of H^2S inhibits cytochrome oxidase enzyme which is critical to mitochondrial respiration in the cells. Nervous and cardiac tissues, which have a higher oxygen demand, are especially disturbed by cellular apoptosis and may result in death.

Managing undesirable effects

It is highly unlikely that any single feedstuff or additive will cause direct S toxicity in poultry. Nevertheless, the total S supply (in feed and water) should be monitored to avoid S content in excess of 3500ppm, especially if S-rich ingredients are included in the formulation. At such levels, it is important to consider sulphur supply in the dEB equation to ensure that the acidogenic potential of the feed is not neglected. Alongside this wellbeing-related practice, the use of trace minerals from high quality oxide sources, free of S, can contribute to minimize sulphate content of diets.

Table 1 – Simulation of S impact on dEB according to the equation model used.

	Low S diet (2400ppm) DEB in mEq/kg	High S diet (3500ppm) DEB in mEq/kg	dEB interpretations
Current and commonly used DEB equation (Na^++K^+)-(Cl^-)	200	207.8	Both diets are very similar and conform to performance level
Mongin's (1981) equation (Na^++K^+)-(Cl^-+S04-)	189.9	166.4	The dEB of both diets differ and are below the reference value

This simulation clearly shows the importance of considering sulphur in the dEB calculation.