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Copper in ruminants: beware of going from deficiency to toxicity

It has long been recognised that copper (Cu) is an essential trace element in ruminants. As copper is required in many key enzymes, any sub-clinical deficiency will impair animal health, fertility and production performance.

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Copper requirements and the maximum copper level authorised in the European Union are presented in Table 1. For bovine, the requirements are around 10mg/kg DM with higher values (up to 18mg/kg DM) for dairy cows in the close-up period and in the first weeks after parturition. Higher values are recommended for caprine (up to 25mg/kg DM) but lower for ovine (up to 10mg/kg DM) which are highly sensitive to excess copper.

A genetic variation observed in copper absorption can also influence copper requirements. Literature mentions in particular higher requirements in Scottish Blackface than in Texel sheep and in Jersey than in Holstein Friesian cows.

After the 2016 EFSA Opinion on the revision of maximum contents of dietary copper, the maximum EU copper level authorised in bovine feed recently decreased from 35 to 30ppm, while it increased from 25 to 35ppm for caprine (Regulation (EU) 2018/1039).

In ruminants, copper is not used at growth promoting dosages like it is in monogastric diets. Thus, the re-evaluation of maximum copper levels is not driven by environmental concerns but more by nutritional objectives.

Poultry and pigs have copper requirements well established for decades, in ruminants and especially bovine, more research is still needed. This is due to the high sensitivity of ruminants to copper with a small margin between deficiency and toxicity, but also to the presence of antagonists in the rumen which can decrease the availability of copper for the animal.

Risk of secondary deficiencies

Copper deficiency is occasionally observed in ruminants. Mineral deprivation occurs due to either a primary or a secondary deficiency. The primary deficiency is the ‘classic’ form, in which low levels of copper are supplied in the diet and do not meet animal requirements for this mineral.

This scenario is most unlikely to happen, because the main ingredients of the diet meet the animals’ need for copper, as shown in Table 2. On top of the basal diet, mineral feeds are usually added in order to secure a large safety margin.

Secondary deficiency happens when even at the proper level of copper supplementation, the presence of other dietary factors interferes with mineral absorption and metabolism.

This phenomenon is the main cause of copper deficiency in ruminants. Sulphur (S), molybdenum (Mo) and iron (Fe) are the most important dietary factors to negatively impact copper absorption.

In the rumen, molybdenum and sulphur interact, forming complexes called thiomolybdates (TM). The nomenclature follows the level of sulphur chelation: mono (TM-1), di (TM-2), tri (TM-3) or tetra (TM-4) - thiomolybdate.

Fig. 1 illustrates how these metals interact in the rumen; TM-1 and TM-2 are less stable bonds and most likely reversible in the acidic environment of the abomasum, as TM-3 and TM-4 are more stable and with a greater affinity for copper.

Fig. 1. Schematic representation of interactions between sulphur (S), molybdenum (Mo) and copper (Cu) in the rumen.

Table 1. Cu requirements and maximum Cu dietary level authorised in the EU for ruminants (mg/kg complete feed).

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Bovines before the start of rumination</th>
<th>Other bovine</th>
<th>Small ruminants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beef</td>
<td>Dairy</td>
<td>Ovine</td>
</tr>
<tr>
<td>CVB, NL (2005)</td>
<td>10</td>
<td>11-13</td>
<td>7-17</td>
</tr>
<tr>
<td>Agroscope, CH (2006, 2009)</td>
<td>6</td>
<td>10</td>
<td>10-15</td>
</tr>
<tr>
<td>INRA, FR (2018)</td>
<td>--</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Maximum Cu dietary levels authorised</td>
<td>15</td>
<td>30</td>
<td>15</td>
</tr>
</tbody>
</table>

1 Regulation (EU) 2018/1039
High levels of iron in water and/or diets also lead to copper deficiency, especially in grazing animals. Animals at pasture consume around 10% DM soil, rich in iron, while grazing. The mechanism behind Fe/Cu competition is still not clear, but it is believed that iron associates to sulphur, forming FeS in the rumen. This complex dissolves under the low pH of the abomasum releasing sulphur that may bind to copper, compromising its absorption.

The signs of copper deficiency vary from mild symptoms such as loss of coat condition and poor growth, to more severe symptoms like infertility and diarrhoea.

As forage and diet compositions are seasonal and variable from farm to farm, secondary deficiencies are difficult to predict.

Therefore, copper in ruminant diets is usually supplemented well above nutritional requirements, to guarantee copper absorption regardless of the presence of antagonists (Fig. 2).

The slightest alteration in the dietary concentration of one of these minerals (S, Fe and Mo) can modify the host copper status from deficiency to toxicity.

In comparison to deficiency which has been well documented these last decades, excess copper in large has been well documented these decades, excess copper in large quantities of copper in the liver of dairy cow herds is usually supplemented well and is usually lower than the quantity of copper needed to meet the animal’s requirements, without forgetting drinking water which can be a significant source of iron and sulphur for the animal.

Table 2. Cu concentration in some feedstuffs used in dairy cow diets.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Cu mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass silage</td>
<td>8-10</td>
</tr>
<tr>
<td>Corn silage</td>
<td>4</td>
</tr>
<tr>
<td>Beet pulp</td>
<td>9</td>
</tr>
<tr>
<td>Sorghum</td>
<td>4</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>14</td>
</tr>
<tr>
<td>Sunflower</td>
<td>20-30</td>
</tr>
<tr>
<td>Rapeseed meal</td>
<td>7</td>
</tr>
</tbody>
</table>

More advanced analytical techniques will be required to understand the effects of the chemical form of these antagonists.

The choice of the source of copper supplemented in the feed is also of importance.

Indeed, copper sources with known physicochemical characteristics and dissolution kinetics can help to select the one which is the less susceptible to form complexes in the rumen.

Copper(I) oxide (CoRouge), recently authorised in the market, combines high bioavailability with a low solubility at rumen pH.

This innovative source of copper will help to restrict the need for higher copper dosages in ruminant diets and to preserve animal productivity, health and welfare.

Fig. 2. Estimated Cu requirement of beef cattle at several dietary Mo and S concentrations (Jongbloed et al, 2005).

Fig. 3. Evolution of copper concentration in cattle liver over the last two decades (Grace and Knowles, 2015; Counette et al, 2019).

Copper toxicity leads to liver damage and jaundice (NADIS).