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Influence of molybdenum and sulfur on copper metabolism in sheep: comparison of elemental sulfur and sulfate

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Summary — French forages usually have low levels of molybdenum, and sulfur contents are often in excess in ruminant feeds. The minimum level of molybdenum able to trigger the copper sulfur molybdenum interference in sheep was measured with either elemental sulfur or sulfate (diets enriched to 5.2 g S/kg DM). Four groups of 5 lambs weighing 35 kg received elemental sulfur and 4 increasing doses of molybdenum in the first experiment. In a second experiment, 6 groups of 5 lambs received sulfate (one group was a control group; the second received sulfate only) and 4 increasing molybdenum doses. The sulfur-molybdenum-copper interference was quantified by the plasma copper fraction insoluble in 5% trichloracetic acid (TCA insoluble copper). Whatever the form of sulfur, the interference appears with a molybdenum level of over 2.4 mg Mo/kg DM. Sulfate interferes less than elemental sulfur with the molybdenum on copper metabolism.

Keywords: molybdenum - sulfur - copper - nutrition - ovine

Résumé — Influence du molybdène et du soufre sur le métabolisme du cuivre chez le mouton : comparaison de l'influence du soufre et de l'ion sulfate. Les teneurs en molybdène des fourrages français sont faibles alors que les excès de soufre sont fréquents dans les rations des ruminants. Le niveau minimum de molybdène susceptible de déclencher une interférence soufre-molybdène-cuivre, chez le mouton, a été mesuré avec du soufre en fleur ou un sulfate (rations enrichies à 5,2 g S/kg MS). Quatre lots de cinq agneaux de 35 kg ont reçu du soufre en fleur et quatre doses croissantes de molybdène; six lots de cinq agneaux ont reçu du sulfate (dont deux lots témoins sans additif ou du sulfate seul) et quatre doses quantifiée par la fraction de cuivre plasmatique insoluble dans l'acide trichloracétique à 5% (cuivre TCA insoluble). Quelle que soit la forme de soufre l'interférence apparaît avec une dose de molybdène supérieure à 2,4 mg Mo/kg MS. Le sulfate interfère moins que le soufre en fleur avec le molybdène sur le métabolisme du cuivre.

Keywords: molybdène - soufre - nutrition - ovin - cuivre

At normal levels, sulfur is used by ruminants in the rumen for sulfur aminoacid synthesis. Sulfur in excess is sometimes introduced in animal diets either through a mineral mix or by contamination. Fuels used for dehydration may contaminate forages with elemental sulfur. Calcium or aluminium sulfate as an auxiliary may be utilized in beet pulp overpressing to enhance dry matter content.
In the rumen, sulfur in excess is reduced to sulfide which, together with molybdenum, induces di- or trithiomolybdate synthesis (Mason, 1982).

Thiomolybdates are copper enzyme inhibitors. They enhance copper attachment to plasmatic albumin (Woods and Mason, 1987). Thiomolybdate synthesis may be quantified by the determination of a plasmatic copper fraction, insoluble in 5% trichloracetic acid (TCA) (Lamand et al., 1980; Mason, 1982).

In France, forages or ruminant feeds rarely possess a molybdenum content > 3 mg Mo/kg dry matter (DM) (Lamand, 1981).

We therefore wished to determine the minimal doses of molybdenum necessary to trigger the sulfur-molybdenum-copper interference either with sulfur as elemental powder or with sulfate ions.

Materials and Methods

In the first experiment, 20 Limousin x Romanoff lambs weighing 35 kg on average were divided into 4 groups of 5 animals. They received a diet based on hay (200 g/day) and concentrate (corn 40% and dehydrated lucern 60%, 1 kg/day). With a mineral mix, the diet was enriched to 7 mg Cu/kg DM. Its sulfur content was 2.2 g/kg DM. It was enriched with 3 g/kg of elemental sulfur. In the groups 1 - 4, the diets were increased respectively to 2.4, 4.8, 7.2 and 9.6 mg Mo/kg DM with ammonium molybdate administered per os.

In the second experiment, 30 lambs (6 groups of 5 animals) received the same basal diet (control) enriched either with sulfur or with increasing doses of molybdenum as previously. In this experiment, the sulfur (3 g/kg DM) was introduced in the diet as anhydrous sodium sulfate (16 g/kg DM). Plasma was prepared from blood samples obtained twice a week. Trace elements and plasma trichloracetic insoluble copper fraction (TCA insoluble copper) were determined as already described (Lamand et al., 1980).

The evolution of TCA insoluble copper fraction was followed in each group by Mann-Whitney's non-parametric U-test and for the whole group by the Kruskal-Wallis H-test (Snedecor and Cochran, 1957).

Results

Lambs fed with elemental sulfur (Exp. 1)

From the 4th day, in the groups receiving 4.8, 7.2, 9.6 mg Mo/kg DM, the molybdenum induced an increase in the TCA insoluble copper fraction (Fig. 1). The minimal dose of molybdenum (2.4 mg/kg DM) did not have significant effect. The TCA insoluble copper fraction increased to a plateau of = 2, 4, 3.4, 5.6 µmol/l respectively in the lambs receiving 4.8, 7.2, 9.6 mg Mo/kg DM from the 7th day. When equilibrium was obtained, the TCA insoluble copper was proportional to the molybdenum level (r = 0.98).

Lambs fed with sulfate (Exp. 2)

The influence of the molybdenum on the TCA insoluble copper fraction was significant from the 3rd day in lambs receiving 7.2 and 9.6 mg Mo/kg DM (Fig. 2). The

![Fig. 1. Evolution of the copper TCA insoluble fractions in the 4 groups of lambs receiving a diet enriched in molybdenum and sulfur (3 g S/kg DM).]
animals from the control group or sulfate only group with no TCA insoluble copper fraction are not shown in the figure. For the second level of molybdenum (4.8 mg Mo/kg DM) the TCA insoluble copper fraction was only significant from the 20th day. In lambs receiving 7.2 and 9.6 mg Mo/kg DM, the levels of TCA insoluble copper fractions were not significantly different.

The plateau for TCA insoluble copper, reached after 6 days for lambs fed with 4.8, 7.2 and 9.6 mg Mo/kg DM were respectively 0.6, 2.1 and 2 μmol/l. These levels were not correlated with the molybdenum intake (r = 0.93; NS).

To compare the 2 experiments, the sulfate induced TCA insoluble copper fractions that were significantly lower than the elemental sulfur (at an identical molybdenum level). It should be noted that 16 g of anhydrous sodium sulfate/kg DM of feed did not bring about any digestive disorder, either during the transition to the sulfur enriched diet or during the experiment.

Discussion

In the control and in the lambs receiving sulfur only the TCA insoluble copper fraction did not appear as previously observed (Lamand et al., 1980). As with elemental sulfur or sulfate, the sulfur-molybdenum-copper interference is early: it appears in 3 or 4 days. It then evolves to a plateau (at identical molybdenum level) that is higher for elemental sulfur than for sulfate.

The sulfur-molybdenum-copper interference is therefore more significant with sulfur than with sulfate. The TCA insoluble copper fraction is proportional to the molybdenum intake with elemental sulfur, but not with the sulfate. With this latest form the levels of TCA insoluble copper are not different with 7.2 or 9.6 mg Mo/kg DM, which suggests that the sulfide level produced in the rumen is probably limiting for thiomolybdate synthesis.

This result may be explained by the different behaviour of the two forms of sulfur. The elemental sulfur generates sulfides quickly and intensively (Bray and Till, 1975) while the sulfate is reduced more slowly by the rumen flora and may be incorporated in bacterial proteins without any detectable sulfide production (Whanger, 1972).

However, the minimum level of molybdenum necessary to trigger the S-Cu-Mo interference is the same: the first dose (2.4 mg Mo/kg DM) does not induce any interference, but the level of 4.8 mg Mo/kg DM produces this interference early with elemental sulfur (7th day) and later (20th day) with sulfate.

It may be concluded that with a diet containing 5.2 g of sulfur/kg DM either from elemental sulfur or sulfate, the minimum molybdenum to trigger the sulfur-copper-molybdenum interference is > 2.4 mg of molybdenum/kg DM, probably near the 3 mg/kg DM suggested by Underwood (1966).

However, the sulfate interferes less than the elemental sulfur if the sulfur-cop-
per-molybdenum interference is quantified by the plasma copper TCA insoluble fraction.

References


