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COPPER, ZINC AND MOLYBDENUM IN LIVERS OF NORWEGIAN CATTLE AT SLAUGHTER

By

Arne Frøslie, Gunnar Norheim and *Erling Waasjø*

FRØSLIE, ARNE, GUNNAR NORHEIM and ERLING WAASJØ: *Copper, zinc and molybdenum in livers of Norwegian cattle at slaughter.* Acta vet. scand. 1980, *21*, 62—70. — The concentrations of copper, zinc and molybdenum were measured in samples of cattle liver from 10 slaughter-houses in Norway. A total of 335 samples were analysed. A clear accumulation of copper with age was found, the average copper level in the younger animals (≤ 3 years, n = 194) being 30 µg Cu/g liver wet weight, and in the older ones (> 3 years, n = 141) 59 µg Cu/g. The range in the copper values found was considerable, though significant differences between some of the districts were recorded. Copper concentrations were classified as low (≤ 10 µg Cu/g) in 9.6 % of the samples. Zinc showed no accumulation with age, nor were there any differences in zinc levels found in animals from different districts, the average level being 32 µg Zn/g liver wet weight. The picture was the same for molybdenum, no differences between age groups or districts being found. The average level was 1.0 µg Mo/g liver. There was no significant correlation between levels of copper, zinc or molybdenum.

The supply of copper and zinc to cattle in Norway seems close to sufficient, but copper- and zinc-fortified mineral supplementation of cattle feed is still to be recommended. There seems to be no need for molybdenum supplementation in cattle.

copper; zinc; molybdenum; cattle; liver.

Copper-related deficiency diseases in cattle in Norway were first described by *Ender* in 1942. Since then he and his coworkers have reported copper deficiency in cattle in several districts in the country (*Havre et al.* 1960, *Havre & Dynna* 1961, *Dynna & Havre* 1963, 1966, *Havre* 1970). These reports were mainly based on clinical examinations of the animals and chemical analysis of grass. Only a very few analyses of liver or blood samples have been carried out.

In the present paper, the results of analyses of bovine liver for copper and for the interfering elements zinc and molybdenum are reported.

MATERIALS AND METHODS

Samples of bovine liver were collected at 10 slaughter-houses, the locations of which are given in Table 1. The samples originated from slaughtered animals varying in age from 3/4 to 7 years according to estimations by the meat inspectors. Copper, zinc and molybdenum levels in the liver samples were determined as described by *Frøslie & Norheim* (1976) and *Norheim & Waasjø*

Table 1. The concentrations of copper, zinc and molybdenum (μg/g wet weight) in bovine liver from 10 districts in Norway. The copper levels are grouped according to age. The number of samples with copper concentrations below 10 μg/g are given.

Location of slaughter-houses	Copper					Zinc			Molybdenum		
	age (years)	number	mean μg/g	range	number ≦ 10 μg/g	number	mean μg/g	range	number	mean μg/g	range
Sarpsborg	≦ 3	18	31	8.6—81	2	30	34	25—97	10	1.1	0.8—1.3
	> 3	12	61	16 —97	0						
Oslo	≦ 3	18	39	6.4—97	1	30	32	14—44	10	1.0	0.6—1.1
	> 3	12	85	37 —105[1]	0						
Lillehammer	≦ 3	23	35	10 —69	2	30	31	25—51	10	1.1	0.9—1.2
	> 3	7	82	43 —120	0						
Skien	≦ 3	21	26	1.7—43	3	42	32	25—102			
	> 3	21	58	4.0—120	1						
Stavanger	≦ 3	17	18	3.4—45	5	32	30	24—44	10	1.0	0.7—1.2
	> 3	15	51	6.8—98	1						
Bergen	≦ 3	17	34	7.8—82	2	30	30	14—54	10	1.0	0.7—1.1
	> 3	13	53	6.4—102	2						
Ålesund	≦ 3	20	37	14 —80	0	41	33	25—90			
	> 3	21	74	13 —107	0						
Steinkjer	≦ 3	21	30	3.0—71	2	30	32	23—49	10	1.0	0.8—1.1
	> 3	9	66	24 —95	0						
Bodø	≦ 3	19	16	3.0—63	9	30	32	24—54	9	1.0	0.7—1.2
	> 3	11	37	12 —68	0						
Tromsø	≦ 3	20	28	10 —49	1	40	31	23—54			
	> 3	20	45	4.8—73	1						
Sum	≦ 3	194	30	1.7—97	27	335	32	14—102	69	1.0	0.6—1.3
	> 3	141	59	4.0—120[1]	5						

[1] One single value of 240 μg Cu/g is excluded from the calculations.

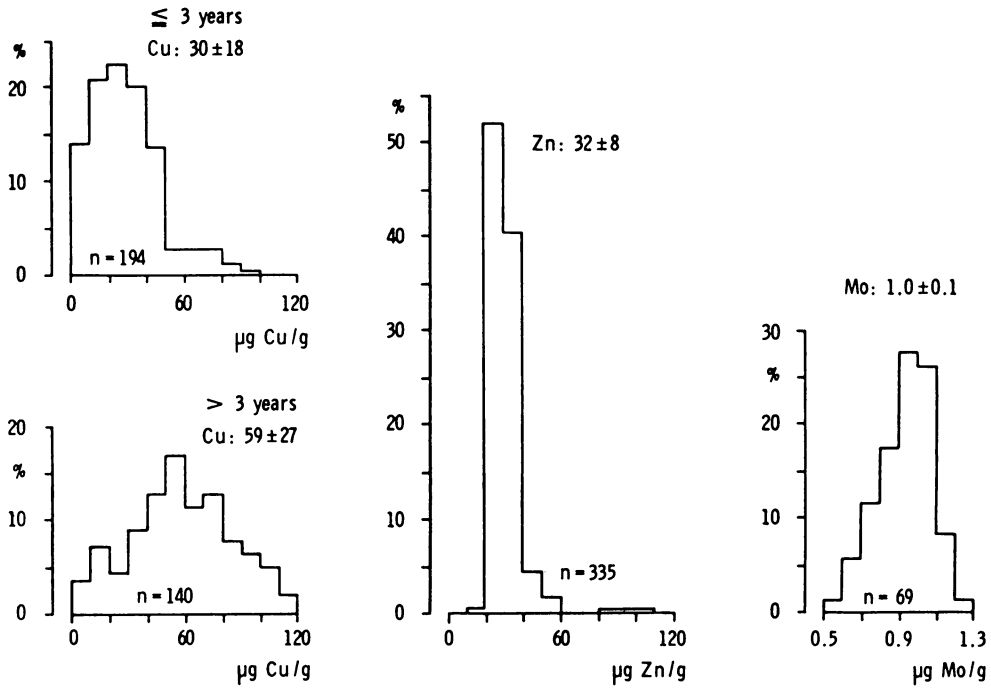

Figure 1. Histograms showing the distribution of samples as a function of the hepatic concentrations of copper (left), zinc (middle) and molybdenum (right) in Norwegian cattle at slaughter. The copper levels have been split up according to the age of the animals, those ≦ 3 years (upper curve) and those > 3 years of age (lower curve). The mean values, the standard deviations and the number of samples are given. One single copper concentration of 240 µg/g in a sample from the group of older animals has been excluded from these calculations.

(1977). All concentrations are expressed on a wet weight basis in µg/g.

RESULTS

Analytical results are shown according to district in Table 1, while histograms of the samples are given in Fig. 1.

As the variation in liver copper concentration varied with age, the material was split in two age groups, animals younger or older than three years. Liver copper levels in the older animals were about twice as high as those in the younger animals, 59±27 µg/g and 30±18 µg Cu/g, respectively. There were great variations within the groups from the different districts and a con-

siderable overlapping in the range of levels recorded. The differences between the two age groups were significant for all districts ($P < 0.05$—$P < 0.001$).

There was also certain differences in the copper concentration in animals from different districts. The values recorded in young animals at Stavanger and Bodø were only about half those from other districts ($P < 0.05$—$P < 0.001$). The differences recorded between the other eight districts were not significant. The differences in copper levels are also illustrated by the frequencies of samples below 10 µg/g. As seen from the table, the number of such samples was highest in Stavanger and Bodø. Copper levels below 10 µg/g were found in 27 samples (14 %) from young animals, while in older animals only five samples (about 3.6 %) were below this level.

The zinc values varied less than the copper values. The mean value for all samples was 32 ± 8 µg Zn/g. No significant differences were found between age groups or between different districts.

As regards molybdenum, there were no significant differences between age groups or geographical areas. Mean and standard deviation of all the samples ($n = 69$) was 1.0 ± 0.1 µg Mo/g. No significant correlation between molybdenum and zinc, molybdenum and copper, or copper and zinc was found in the present material ($r < 0.15$).

DISCUSSION

According to this investigation, the copper status in most Norwegian cattle is satisfactory, although copper levels in 9.6 % of the tested livers are considered to have been low (≦ 10 µg Cu/g).

The optimal level of copper in bovine liver seems to vary between 100 and 200 µg/g dry weight (d.w) (*Rosenberger* 1970, *Blood et al.* 1979). Applying a figure of about 30 % dry matter in bovine liver, this is equivalent to 30—60 µg/g wet weight (w.w.). The authors mentioned above state the marginal level for deficiency to be 12 µg/g d.w. (∞ 3.5 µg/g w.w.). The *Committee on Mineral Nutrition* (1973) in the Netherlands states the normal value in bovine liver to be 150 µg Cu/g d.w. (∞ 45 µg/g w.w.), the marginal level 25 µg Cu/g d.w. (∞ 8 µg/g w.w.) and the deficiency level 3 µg Cu/g d.w. (∞ 1 µg/g w.w.). Acoording to *Blood et al.* levels below 30 µg Cu/g d.w. (∞ 10 µg Cu/g w.w.) should

be classified as low. The last-mentioned level is used in the present investigation as a criterion for suboptimal copper supply.

As regards the copper status of domestic ruminants in Norway, there is a fundamental difference between sheep, on the one hand, and cattle and goats on the other (*Frøslie & Norheim* 1976, *Frøslie* 1977, *Søli & Frøslie* 1979). Average copper values in sheep are considerably higher than in goats and cattle. The range in values is wider, extending from submarginal levels to levels exceeding those at which toxicosis occurs. These differences probably reflect species differences in the ability to accumulate copper (*Hill* 1977 a, b), though nutritional considerations are probably also of some importance. These matters are not yet fully understood.

A difference in copper levels has been demonstrated between sheep from typical inland areas and those from coastal areas (*Frøslie*). Copper toxicosis in sheep is mainly a problem of typical inland areas. In the Rogaland county in southwestern Norway, copper levels in both sheep and cattle are relatively low. In other districts the copper status of sheep does not relate very well to that of cattle. For example, copper levels in sheep from the Bodø region are rather high, and yet values found in cattle from this region were lower than in any of the other groups of cattle examined. This may reflect pronounced regional differences concerning natural and cultivated pastures, sheep grazing to a large extent on natural pastures. The fact that regional differences were less pronounced in cattle may also be due to more extensive use of concentrates in cattle than in sheep. Only small amounts of concentrates are used in sheep, while about half the total amount of concentrates distributed in Norway is included in standard feed mixtures for cattle (*Statens Kornforretning* 1978). These mixtures contain copper and other minerals. Standard mineral mixtures for ruminants and horses contain 1,000 mg Cu/kg. Mineral supplements which have not been standardized usually also contain copper. Had these sources of copper been in general use in cattle nutrition in Norway, regional differences in bovine copper status would have been small, and problems related to deficient copper supply would probably not have arisen. However, the present investigation has shown that copper levels are still somewhat low in parts of the Norwegian cattle population, especially in the younger animals. The age-related copper accumulation in cattle corresponds to the situa-

tion in sheep (*Frøslie & Norheim* 1976) and swine (*Frøslie & Norheim* 1977). Cases of chronic sickness responsive to copper supplementation have been reported in certain districts of the country (*Øverby* personal communication 1979, *Larssen* personal communication 1979). Such reports supply evidence of occurrence of copper deficiency disorders.

Rosenberger reported a zinc level in livers of healthy calves of 125—170 μg Zn/g d.w. (≈ 38—51 μg/g w.w.), while the concentration in livers of calves suffering from parakeratosis was 100—125 μg/g d.w. (≈ 30—38 μg/g w.w.). If these deficiency limits are relevant for cattle at slaughter, a large part of the cattle population in Norway is deficient in zinc. More than 50 % of the liver samples were below 30 μg Zn/g w.w. The local occurrence in Norway of a complex zinc-copper deficiency condition has been described (*Dynna & Havre* 1963), but apart from this, zinc deficiency in cattle is not considered to be a problem in Norway (*Krogh* personal communication 1979). Standard mineral mixtures contain 2,400 mg Zn/kg. Liver levels of zinc in cattle are, however, significantly lower than those in sheep and swine (*Frøslie & Norheim* 1976, 1977), but about the same as those found in goat (*Søli & Frøslie*). The distribution of copper- and zinc-binding proteins in cattle liver with zinc concentrations below 40 μg/g (*Mjør-Grimsrud & Norheim* 1980) was quite similar to that found in zinc deficient sheep by *Bremner & Marshall* (1974).

Hellesnes et al. (1975) found regional differences in zinc concentrations in bovine liver. Corresponding variations were not found in the present investigation. The lowest levels found by *Hellesnes et al.* were in liver samples from the Lillehammer region, 133 ± 24 μg Zn/g d.w. (≈ 40 μg/g w.w.), and the highest in samples from the Tromsø region, 250 ± 38 μg Zn/g d.w. (≈ 75 μg/g w.w.). These figures are considerably higher than in the present material.

According to *Underwood* (1977) molybdenum levels in the livers of a majority of animal species are in the range 2—4 μg/g d.w. (≈ 0.6—1.2 μg/g w.w.). The levels found in the present investigation, and those found in other farm animals (*Frøslie & Norheim* 1976, 1977, *Søli & Frøslie*), are within these limits. *Rosenberger* states that the molybdenum levels in cases of clinical molybdenosis lie between 2.5 and 5.0 μg Mo/g liver tissue w.w. Such high levels have, to the authors' knowledge, never

been measured in bovine liver in Norway. *Brockman* (1977), however, reported that 10 of 40 livers of slaughtered cattle from Saskatchewan, Canada, had molybdenum levels greater than 2.0 µg/g w.w. In the same material, comprising 152 samples, he found that 67 % of the samples had copper concentrations below 10 µg/g liver w.w. In such districts molybdenum loading is probably a major factor in the development of copper deficiency. This is in contrast to the situation in Norway.

It can be concluded from the present investigation that the supply of copper and zinc to the majority of cattle in Norway is close to sufficient, but copper- and zinc-fortified mineral supplementation is still to be recommended. There seems to be no need for molybdenum supplementation in cattle.

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SAMMENDRAG

Kobber, sink og molybden i lever fra norsk storfeslakt.

Det ble samlet i alt 335 leverprøver fra storfe ved 10 forskjellige slakterier i Norge. Dyrenes alder ble anslått ved kjøttkontrollen. Alle prøvene ble analysert med hensyn på kobber og sink. Molybdeninnholdet ble bestemt i 69 prøver. For alle distriktene ble det påvist en klar kobberakkumulering med alderen. Gjennomsnittsnivået for unge dyr ($\leq$ 3 år, n = 194) var 30 µg Cu/g lever våtvekt, mens det for eldre dyr ($>$ 3 år, n = 141) var 59µg Cu/g lever. Det var en betydelig spredning i kobbernivåene i leverprøvene fra de forskjellige slakteriene. For unge dyr slaktet i Bodø og Stavanger var alikevel kobbernivåene signifikant lavere enn i unge dyr slaktet ved andre slakterier. I 9,6 % av prøvene må kobbernivåene klassifiseres som lave ($\leq$ 10 µg Cu/g). For sink ble det ikke funnet noen akkumulering med alderen. Det ble

heller ikke funnet noen forskjeller i sinknivået i prøvene fra de forskjellige distriktene. Det gjennomsnittlige sinknivået var 32 µg Zn/g lever våtvekt. Heller ikke for molybden ble det funnet noen aldersakkumulering eller noen forskjeller mellom distriktene. Det gjennomsnittlige molybdennivået var 1,0 µg Mo/g lever. Det ble ikke funnet noen korrelasjon mellom konsentrasjonene av kobber, sink eller molybden i prøvene.

Tilskuddet av kobber og sink til storfe i Norge er nær opp til behovet, men det må fortsatt anbefales å bruke mineralblandinger tilsatt kobber og sink. Det synes ikke å være noe behov for tilskudd av molybden til storfe.

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