Acta vet. scand. 1975, *16*, 481—491.

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SELENIUM AND ZINC CONCENTRATIONS IN KIDNEY, LIVER AND MUSCLE OF CATTLE FROM DIFFERENT PARTS OF NORWAY

By

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HELLESNES, I., B. UNDERDAL, G. LUNDE and G. N. HAVRE: *Selenium and zinc concentrations in kidney, liver and muscle of cattle from different parts of Norway.* Acta vet. scand. 1975, *16*, 481—491. — Cattle slaughtered in four different parts of Norway have been examined with respect to selenium and zinc content in kidney, liver and muscle. Highest selenium concentrations were found in kidney and lowest in muscle. In spite of extensive use of standardized concentrates, geographic differences were detected with regard to selenium tissue levels, animals from the southeastern inland region having the lowest levels. According to other workers, this region has low-selenium humus soils, and selenium responsive diseases among young ruminants have been of considerable importance, especially when concentrates had not been given during winter feeding. The recorded tissue selenium levels are compared to other workers' proposals for normal values. All animals examined in this study seem to be well within healthy limits. Kidney, liver and muscle from cattle are good sources of selenium with respect to human nutrition.

As far as zinc concentrations are concerned, muscle has the highest and kidney the lowest levels. Geographic differences were found, and individuals from the midland and northern coastal regions have the highest zinc tissue levels. Cattle from the northern coastal region seems to have especially high zinc concentrations in the organs.

trace elements; selenium; zinc; cattle; kidney; liver; muscle.

The effect of trace elements on living organisms may be both beneficial and detrimental, and some of the elements may act in both ways depending on the concentration. Selenium and zinc belong to the latter group. Interest in selenium was initially confined to its toxic effects in animals. The existence of naturally occurring selenosis was demonstrated in stock animals 40 years ago by American scientists, and the manifestations were an acute form called "blind staggers" (*Beath et al.* 1935) and the chronic form of selenium excess called "alkali disease" (*Robinson* 1933). According to *Flatla* (1967) naturally occurring selenosis has not been registered in Norway.

Since 1957 attention has been focused on the physiological rather than the toxicological role of selenium. In this and the following years many studies were performed, giving indications for the possible significance of selenium and its importance in a variety of disorders in animals (*Schwarz & Foltz* 1957, *Patterson et al.* 1957, *Muth et al.* 1958, *McLean et al.* 1959). Naturally occurring deficiency areas were soon demonstrated, and regions in the Scandinavian countries were shown to be among them (*Anderson* 1960, *Oksanen* 1965, *Mikkelsen & Hansen* 1967, 1968, *Lunde & Ødegaard* 1972). One of the deficiency diseases responsive to selenium is nutritional muscular disease (NMD), which has been known to occur to a great extent in cattle and sheep in different areas of Norway (*Slagsvold & Lund-Larsen* 1934). Nowadays, however, NMD is most often seen in young sheep, but rarely in cattle (*Mikkelsen & Hansen* 1967). In recent years, two investigations on blood serum and tissue selenium levels in sheep in Norway have been carried out (*Mikkelsen & Hansen* 1967, *Lunde & Ødegaard* 1972), while information on selenium concentrations in tissues from Norwegian cattle has not been published.

During later years, the relationship of selenium to various human disorders, such as cancer (*Scott* 1973), dental caries (*Hadjimarkos* 1973) and the sudden infant death syndrome (*Rhead et al.* 1972) has been discussed. Although definite proof for the significance of selenium in cancer and the sudden infant death syndrome seems to be lacking, research on selenium levels in human foodstuffs is indicated.

The main purpose of the present work was to determine tissue levels of selenium. Using neutron activation analysis for the determination of selenium the γ-ray spectrum also revealed the content of zinc, and we therefore report the results for both. The necessity of zinc for rats was established in 1934 (*Todd et al.*). Since then, proof has been given for naturally occurring deficiencies in swine, poultry and cattle (*Underwood* 1971 a). *Dynna & Havre* (1963) demonstrated zinc deficiency in Norwegian cattle. Accidental high intake of zinc may cause symptoms of intoxication.

The present investigation was carried out to determine the trace element concentrations in Norwegian cattle, raised in different parts of the country. However, since locally produced feedstuffs constitute only a part of the total feeding, marked regional differences were not expected. The distribution in the organism, indicated by the levels in kidney, liver and muscle tissue was also of interest.

MATERIALS AND METHODS

Tissue samples were obtained from four slaughter-houses situated in different regions of Norway. These were Rogaland Sentralslakteri, Stavanger (southwestern, coastal region), Hed-Opp Slakterier A/L, Lillehammer (southeastern, inland region), Bøndernes Salgslag, Trondheim (midland, coastal region) and Nord-Norges Salgslag S/L, Tromsø (northern, coastal region). The animals were divided into three groups according to estimated age — less than 2 years, between 2 and 6 years and more than 6 years old individuals.

The animals sampled were of the Norwegian Red Cattle Breed (NRF), which is considered a high-yielding milk-breed with medium meat production qualities. The feeding consists mainly of locally produced grass, fresh or preserved in different ways (hay, silage, lye-soaked straw) and centrally blended grain feeds. The latter contain both home-grown and imported ingredients in varying quantities.

Kidney, Lobus caudatus of the liver and a muscle on the foreleg were taken from each animal. Parts of the samples, weighing from 10 to 15 g, were freeze-dried and homogenized, and aliquots placed in glass ampoules for neutron activation analysis. According to *Underwood* (1971 b), kidney cortex is the tissue with the highest selenium concentration. As the distribution of selenium in renal tissue is not homogenous, kidneys from some of the animals were separated into cortex and marrow.

Samples were taken from 5 animals in each group and region, a total of 60 animals. The separated kidney marrow and cortex samples were taken from 10 animals, more than 6 years old, and slaughtered in Stavanger.

Selenium and zinc were determined by neutron activation analysis as described by *Lunde* (1970). The statistical calculations of correlation were carried out in two ways, the results obtained as "< 0.0n" being estimated both being equal to zero and equal to the detection limit indicated, and we report the lowest significance levels obtained.

RESULTS

The results from the selenium and zinc analyses on kidney, liver and muscle are shown in Tables 1—4, all figures being given in parts per million (p.p.m.) on a dry matter basis. In the 60 animals, kidney selenium concentrations ranged from 2.5 to 7.5 p.p.m., while the liver and muscle levels of the same element ranged from 0.1 to 1.0 p.p.m. and from < 0.06 to 0.62 p.p.m., respectively.

Significant differences according to analysis of variance were found between the kidney selenium levels in the Tromsø-group and all the other groups, the significance probabilities being: $P < 0.02$ (Tromsø-Trondheim), $P < 0.001$ (Tromsø-Lillehammer), $P < 0.03$ (Tromsø-Stavanger). Other significant differences between the regional kidney selenium levels were not found.

Calculation of correlation revealed significant correlation ($P < 0.05$) between the muscle levels and the levels in kidney and liver, the correlation coefficients being $r = 0.30$ (muscle-liver) and $r = 0.40$ (muscle-kidney). Significant correlation between liver and kidney concentrations could not be found.

Table 1. Selenium and zinc concentrations in freeze-dried tissues of cattle from the Lillehammer region (p.p.m. dry matter).

Age	Kidney		Liver		Muscle	
	Se	Zn	Se	Zn	Se	Zn
< 2 years	3.00*	110	0.30	143	0.11	246
	2.7—3.5**	94—137	< 0.18—0.48	120—178	< 0.06—0.24	161—317
2—6 years	4.26*	101	0.32	122	0.21	298
	3.1—5.7**	80—119	0.21—0.44	104—138	< 0.08—0.45	241—388
> 6 years	3.84*	108	0.37	143	0.11	304
	3.1—4.6**	83—126	0.29—0.42	122—195	< 0.06—0.32	240—354
Mean ± s for all age groups	3.70±0.90	106±17	0.33±0.12	136±24	0.15±0.16	283±56

* Mean for 5 animals. ** Range.

Analysis of variance between the age groups was performed with respect to all tissue types, the only significant difference ($P < 0.05$) being between kidney selenium levels in young and middle aged cattle.

The tissue levels of zinc were for kidney 80—248 p.p.m., liver 98—427 p.p.m. and muscle 110—552 p.p.m.

Significant correlations ($P < 0.001$) were found between the three tissue types as far as zinc levels were concerned, the coeffi-

Table 2. Selenium and zinc concentrations in freeze-dried tissues of cattle from the Stavanger region (p.p.m. dry matter).

Age	Kidney		Liver		Muscle	
	Se	Zn	Se	Zn	Se	Zn
< 2 years	4.66* 3.6—6.3**	96 90—110	0.88 0.7—1.0	122 106—150	0.35 0.31—0.40	204 143—281
2—6 years	4.56* 3.4—6.4**	102 95—108	0.45 0.16—0.73	139 98—258	0.19 < 0.06—0.33	244 214—287
> 6 years	4.88* 4.5—5.2**	92 87—96	0.54 0.38—0.6	110 100—115	0.26 0.04—0.51	246 230—274
Mean ± s for all age groups	4.70±0.86	97±7	0.62±0.24	124±39	0.27±0.13	231±40

* Mean for 5 animals. ** Range.

Table 3. Selenium and zinc concentrations in freeze-dried tissues of cattle from the Trondheim region (p.p.m. dry matter).

Age	Kidney		Liver		Muscle	
	Se	Zn	Se	Zn	Se	Zn
< 2 years	4.26* 2.5—6.3**	172 129—191	0.36 0.20—0.7	214 174—262	0.16 < 0.07—0.35	432 178—531
2—6 years	5.64* 4.8—6.6**	176 92—248	0.63 0.48—0.72	261 105—427	0.24 0.16—0.32	394 175—550
> 6 years	3.68* 3.1—4.2**	113 92—138	0.46 0.27—0.73	149 112—213	0.17 < 0.06—0.27	208 110—254
Mean ± s for all age groups	4.53±1.28	154±47	0.48±0.21	208±84	0.19±0.11	345±153

* Mean for 5 animals. ** Range.

Table 4. Selenium and zinc concentrations in freeze-dried tissues of cattle from the Tromsø region (p.p.m. dry matter).

Age	Kidney		Liver		Muscle	
	Se	Zn	Se	Zn	Se	Zn
< 2 years	5.36*	203	0.22	262	0.30	466
	4.8—6.2**	181—225	0.1—0.38	221—311	< 0.07—0.6	419—552
2—6 years	6.32*	195	0.41	241	0.30	435
	5.1—7.5**	186—200	0.30—0.7	223—278	< 0.06—0.62	198—543
> 6 years	5.32*	171	0.33	248	0.26	489
	3.8—7.5**	124—191	0.1—0.6	200—338	< 0.06—0.47	427—542
Mean ± s for all age groups	5.67±1.16	190±22	0.32±0.18	250±38	0.29±0.19	464±88

* Mean for 5 animals. ** Range.

cients being r = 0.65 (muscle-liver), r = 0.72 (muscle-kidney) and r = 0.85 (liver-kidney).

The relationship between selenium and zinc was examined by calculating the correlation, and for kidney the coefficient was found to be r = 0.53 ($P < 0.001$). For the two other tissue types no significant correlation was obtained.

The results concerning kidney cortex and marrow are shown in Table 5. As far as selenium is concerned, cortex contained, on an average, more than twice the amount in marrow. The zinc levels were also highest in cortex. The differences between individual animals were rather small for both elements.

Table 6 shows figures referring to tissue dry matter measured in per cent of the total sample.

Table 5. Selenium and zinc concentrations in kidney cortex and marrow from cattle over 6 years old, slaughtered in Stavanger*.

	Kidney cortex		Kidney marrow	
	Se	Zn	Se	Zn
Mean ± s	5.74 ± 0.40	105 ± 19	2.36 ± 0.49	78 ± 10
Range	4.8 — 6.2	87 — 154	2.0 — 3.6	69 — 104

* Samples from 10 animals.

Table 6. Tissue dry matter in per cent of total sample (w/w).

	Kidney	Kidney cortex	Kidney marrow	Liver	Muscle
Mean ± s	19.9 ± 2.0	20.3 ± 1.3	18.5 ± 1.0	30.5 ± 2.0	24.5 ± 2.1

DISCUSSION

Selenium and zinc levels in tissues of domestic animals are generally assumed to reflect the concentrations in the diet. All cells and tissues of the body contain these trace elements, although considerable differences exist between the various tissues.

A number of diseases have been shown to be responsive to selenium therapy, and the tissue levels of the element are considered a valuable indicator in this respect. *Underwood* (1971 b) states that kidney, and particularly kidney cortex, has the highest concentrations, followed by the glandular tissues, e.g. the liver. The muscles are normally relatively low in selenium content. *Jenkins & Hidiroglou* (1972) propose a normal range for certain livestock animals, including cattle, of 0.3—1.8 p.p.m. in muscle, 0.9—2.5 p.p.m. in liver and 1.8—7.6 p.p.m. in kidney. As far as the present work is concerned, all the kidney values detected are well within these limits, but only the highest concentrations found in muscle are within the range. Furthermore, only a few of the liver samples in our investigation have the selenium content regarded as normal by *Jenkins & Hidiroglou,* and the liver selenium means of the geographical groups are between one third and two thirds of the lowest estimated normal value.

Andrews et al. (1968) indicated the marginal levels for selenium-responsive unthriftiness in sheep to be 0.05 p.p.m. in liver and 0.50 p.p.m. in kidney cortex. Applying these margins to cattle, the individuals sampled in the present study seem to fall well within healthy limits.

Slagsvold & Lund-Larsen (1934) gave a comprehensive description of a nutritional muscular disease among sheep and cattle in a region between Trondheim and Lillehammer (Dovre-Lesja). A recent study by *Låg & Steinnes* (1974) on the selenium content of Norwegian humus soils, showed that the southeastern inland region is low in selenium, and hay from the same region has a low content of the element, according to *Havre & Steinnes*

(1968). An indication of an important soil-plant-animal selenium chain with respect to NMD in sheep in this region was given by *Lunde & Ødegaard* (1972), and a supplement of fish meal in the diet had a good prophylactic effect.

On the whole, the Lillehammer group has the lowest selenium tissue levels in the present study. Thus, locally grown feedstuffs seem to have a detectable influence on the tissue selenium levels in spite of extensive use of concentrates.

In spite of the fact that NMD is a rather important disease in Norwegian sheep, it is seldom encountered in cattle in this country. This may be due to the feeding of young cattle with concentrates, while sheep are fed, to a greater extent, on locally grown hay.

With respect to human nutrition, fresh cattle meat (muscle, liver, kidney) seems to be a good source of selenium. In their broad survey on American foods, *Morris & Levander* (1970) found the highest levels in kidney from cattle, sheep and swine, and they state that meat is only surpassed by seafoods with respect to mean selenium content. The latter fact was confirmed by *Lunde* (1973) who reported a selenium content in meal of different marine fish species ranging from 0.9 p.p.m. to 7.2 p.p.m.

The results from the zinc analyses revealed some regional differences. In samples from Lillehammer and Stavanger, the kidney and liver concentrations were in good agreement with the concentrations referred to by *Lutz* (1926) and *Miller et al.* (1966). The samples from Trondheim and Tromsø contained, on average, 1.5—2 times more, the extremes being 248 p.p.m. (kidney) and 427 p.p.m. (liver).

The muscular zinc concentrations were approx. two to four times greater than the kidney and liver levels, the regional differences still being marked, and with significant correlation within animals. According to *Underwood* (1971 c) the content of zinc in muscle shows a considerable variation depending on the colour and functional activity, with dark and active muscles containing the highest concentrations. The mean value of the Tromsø group, 464 p.p.m., is strikingly high compared to the extreme single value, 332 p.p.m., reported by *Swift & Berman* (1959) in their survey on electrolyte concentrations in eight bovine muscles.

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SAMMENDRAG

Innhold av selen og sink i nyre, lever og muskulatur fra storfe fra ulike deler av Norge.

Til sammen 60 storfeindivider fra 4 steder i Norge er undersøkt for innhold av selen og sink i nyre, lever og muskulatur. Nyrevev hadde det høyeste innhold av selen, og muskulatur det laveste. Levervev inntok en mellomstilling når det gjaldt seleninnhold. Til tross for sterk fóring med standard kraftfórblandinger, ble det påvist geografiske forskjeller i vevsseleninnhold, og lavest nivå ble funnet i dyr fra Lillehammerdistriktet. Det nevnte området har selenfattig jordsmonn,

og selenmangelsjukdom blant ungdyr av små- og storfe har vært et stort problem der, særlig når kraftfór ikke har vært benyttet i inneføringsperioden. De registrerte selenkonsentrasjonene er diskutert i forhold til normer foreslått av andre forskere, og alle de undersøkte dyra synes å være utenfor området for selenmangelsjukdom. Kjøtt og organer fra storfe er gode selenkilder sett i relasjon til human ernæring.

Av de undersøkte vevstypene hadde muskulatur det høyeste og nyre det laveste innhold av sink. Det ble påvist geografiske forskjeller, og dyr fra Trondheim og Tromsø hadde høyest sinkinnhold i vevene. Sammenlignet med resultater oppgitt av andre forskere, synes dyr fra Tromsø å ha svært høye sinkkonsentrasjoner i vevene.

Statistisk bearbeiding av resultatene er foretatt med hensyn på korrelasjoner og signifikante forskjeller på basis av geografiske og aldersmessig fordeling av materialet, mellom elementene selen og sink og mellom organer.

(Received July 16, 1975).

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