Acta vet. scand. 1990, *31*, 287–295.

Ovine White-Liver Disease (OWLD). Serum Copper and Effects of Copper and Selenium Supplementation

By *Martha J. Ulvund*

State Veterinary Research Station for Small Ruminants, Sandnes, Norway.

Ulvund, M. J.: Ovine white-liver disease (OWLD). Serum copper and effects of copper and selenium supplementation. Acta vet. scand. 1990, 31, 287–295. – Serum copper was generally higher in lambs affected with ovine white-liver disease (OWLD) than in cobalt/vitamin B_{12} supplemented lambs grazing the same pastures. Although the copper content of the grass was very low on the OWLD pastures, dosing lambs with Cu alone resulted in worsening of the clinical condition and aggravation of clinical pathology. Dosing with selenium had no effect on OWLD. Dosing with a combination of Co, Se and Cu resulted in normal lamb growth and normal laboratory tests. Lambs growing well on other pastures (H) showed elevated serum Cu when they were subclinically B_{12} deficient.

sheep; cobalt/vitamin B_{12} deficiency.

Introduction

Ovine white-liver disease (OWLD) occurs in vitamin B_{12} deficient lambs in coastal Norway, and may be prevented by supplementation or dosing with vitamin B_{12} (*Ulvund & Pestalozzi* 1990a). On some pastures lambs grow satisfactorily without developing OWLD, although they some years are B_{12} deficient, a fact indicating that cofactors may be decisive as to whether OWLD will develop or not (*Ulvund* 1990a). Examination of grass samples revealed that OWLD grass had significantly lower Cu content than the grass where the lambs had subclinical B_{12} deficiency (*Ulvund & Pestalozzi* 1990b).

There are only few studies on serum Cu in lambs with OWLD and simple Co deficiency. *MacPherson et al.* (1976) reported high plasma Cu in Co deficient sheep, while *Sutherland et al.* (1979) observed high or normal serum Cu in OWLD.

As a concurrent deficiency of both Co and Cu (coast disease) causes illthrift in Australia (*Marston et al.* 1938, *Lee* 1951, *Lee* 1975) and Sweden (*Schwan et al.* 1987), efforts were made to clarify the Co/Cu interaction in OWLD. Selenium responsive unthriftiness has also been reported in lambs (*McLean et al.* 1959), and it was important to evaluate the significance of Se as well.

In this paper serum Cu concentrations in Co/B_{12} deficient lambs with OWLD, in lambs with subclinical Co/B_{12} deficiency, and in Co/B_{12} sufficient lambs are reported. The effect of Cu and Se supplementation on performance and clinical pathology in lambs grazing OWLD pastures is also given.

Materials and methods

A. Serum copper in OWLD lambs and in lambs supplemented with cobalt/vitamin B_{12}

Survey of experimental design has been given (*Ulvund & Pestalozzi* 1990a, *Ulvund* 1990a). Altogether 458 twin lambs of the Dala and Rygja breeds were included in the project (1981–1986). Lambs designed S grazed OWLD pastures, either moderately or heavily Co fertilized (SCo, SCo+) or not Co fertilized (S), and lambs designed H grazed control pastures situated 15 km apart. The H lambs were subclinically B_{12} deficient some years, but they never developed OWLD. Groups of lambs on the OWLD or H pastures were supplemented with Co or regularly injected with vitamin B_{12} as described earlier (*Ulvund & Pestalozzi* 1990a). The supplementation is indicated by symbols, as explained in Tables 1 and 2. Number of lambs sampled within each group was generally 4–6 (*Ulvund* 1990b).

Serum Cu was determined by atomic absorption spectrophotometry according to manufacturer's manual. During 1981–1983 Unicam SP 90 (Unicam Instruments Ltd., Cambridge) was used, while Pye Unicam SP9-200 (Philips) was used during 1984–1986. Seronorm® (Nyegaard & Co. A/S, Oslo) was used as quality control.

B. Copper and selenium supplementation

Group SCuO: Six lambs were dosed with copper oxide needles (Copporal, 2 g, Beecham Animal Health, England) and put on OWLD pastures on May 15, 1984.

Group SCoSeCu: Six lambs on OWLD pastures were dosed (July 1, 1985) with cobalt/selenium/copper pellets (CoSeCure for lambs, 17 g pellets with 13.4 % w/w copper as CuO, 0.3 % w/w selenium as Se, and 0.5 % w/w cobalt as Co_3O_4, Chance Pilkington Ltd., The Wellcome Foundation Ltd., UK). One of the SCoSeCu lambs had no pellet in the forestomachs at slaughter, and had to be excluded from the group.

Group SSe: Six lambs on OWLD pastures were dosed (July 1, 1985) with selenium pellets (Permasel 5 %, ICI, Tasman Vaccine Laboratory, Bury St. Edmunds, Suffolk, UK).

All lambs were weighed weekly. Concentrations of blood constituents were measured as reported earlier (*Ulvund* 1990a, b).

Results

A. Serum copper in OWLD lambs and in lambs supplemented with cobalt/vitamin B_{12}

The unsupplemented S group (OWLD) usually had mean serum Cu above the Co/B_{12} supplemented S groups from the end of July to early/mid September. The lambs which received regular B_{12} injections (SB_{12} lambs) most often had the lowest values. Results from 1982–1984 illustrate this pattern (Fig.

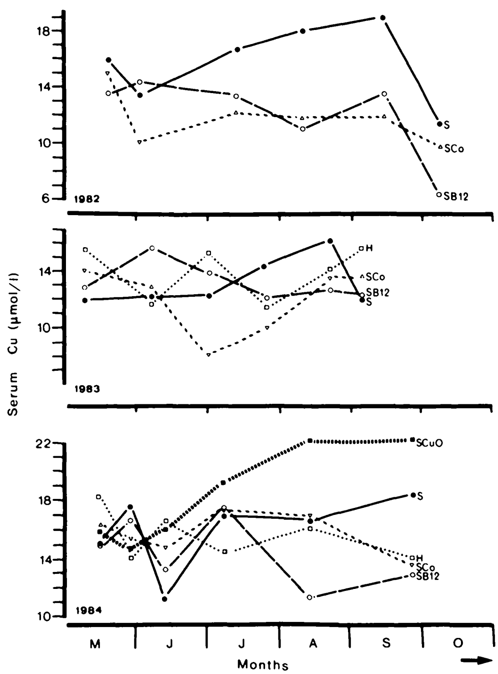

Figure 1. Mean serum Cu (µmol/l) in various groups of lambs throughout grazing in 1982–1984. For group symbols, see Tables 1–3. In 1982, 6 lambs were sampled (n = 6) in the S and SB_{12} groups, while 4 were sampled in the SCo group. In 1983, n was 4 in all groups, except for n = 16 in the S group at the first 4 samplings, and n = 13 at the last two. In 1984, n = 5 in all groups.

Table 1. Mean (± sd) serum Cu (μmol/l), glutamate dehydrogenase (GLDH, U/L), plasma vitamin B_{12} (pmol/l) and methyl malonic acid (MMA, μmol/l) in experimental lambs, 1985. Four lambs were examined in each group (n = 4), except in the SCoSeCu group where n = 3.

		May	June	July	August	October
Cu						
	S	13±0.7	9±1.7	12±2.1	11±0.2	9±2.9
	SSe	13±0.8	9±0.9	13±0.8	15±1.3	12±4.9
	SCoSeCu	15±1.0	12±3.0	11±1.4	10±0.9	13±0.7
	SB_{12}	13±1.7	12±1.8	13±1.3	11±1.8	11±1.8
	H	13±1.4	11±1.1	15±1.8	13±1.7	18±1.1
GLDH						
	S	3±2.4	8±2.7	64±45	37±33	6±0.6
	SSe	9±5.7	16±6.5	42±16	32±16	22±17
	SCoSeCu	3±0.9	5±1.5	6±3.7	7±3.8	11±11
B_{12}						
	S	386±141	117±69	248±254	90±20	556±499
	SSe	445±104	75±20	83±22	153±53	329±56
	SCoSeCu	528±110	92±30	484±113	407±83	656±171
MMA						
	S	0.4±0.3	3.0±0.5	12±8.4	3.5±3.5	1.4±1.2
	SSe	0.6±0.5	5.0±3.0	14±5.8	12±14	2.0±2.3
	SCoSeCu	1.2±0.6	6.0±6.7	1.0±1.1	27±27	3.0±2.9

S : Lambs grazing OWLD pastures.
SCoSeCu: S-lambs dosed on July 1 with CoSeCu pellets.
SSe : S-lambs dosed on July 1 with Se pellets.
SB_{12} : S-lambs injected from July 1 and every second week with vitamin B_{12} (2 mg hydroxocobalamin).
H : Lambs grazing control pastures situated 15 km from the OWLD pastures.

1). The SCo groups had significantly lower values than the S groups ($p < 0.05$) in August 1982 and 1983 and September 1984. In 1985, mean serum Cu in the S lambs was low throughout July-October (Table 1), but the range in individual values was wide (4.7–15 μmol/l). Values for the H lambs were most often in between those of the S and SB_{12} lambs, except in 1985 and 1986, when serum Cu was highest in the H lambs during late summer (Tables 1–2).
Co fertilization (SCo, SCo+) or admittance to Co lick (SColick) had a lowering effect on serum Cu during all years (Fig. 1, Table 2). A similar effect of Co was also seen in H lambs (HCo, HColick, Table 2).

B. Effect of copper and selenium supplementation

The effect of dosing with Cu or Se alone, or together with Co, on live weight (lw) is shown in Fig. 2. Dosing with Cu alone (SCuO) resulted in further weight decrease. When Cu was dosed together with Se an Co (SCoSeCu), performance was good. Dosing with Se (SSe) did not improve weight gain significantly.
Clinically, the 6 SCuO lambs were more

Table 2. Mean (± sd) serum Cu (µmol/l) in various groups of lambs, 1986. Six lambs were examined in each group.

	May	June	August	September	October
S	12±1.9	10±3.5	14±4.0	12±3.5	-
SCo	12±1.6	8±2.5	8±8.5	6±2.8	-
SCO+	13±4.2	11±3.0	10±3.9	9±4.8	-
SColick	11±1.6	10±3.3	10±2.2	8±3.6	-
H	14±3.1	13±0.7	15±2.2	19±2.6	17±4.7
HColick	12±2.0	11±2.3	13±1.7	14±3.4	12±3.5
HCo	12±5.7	12±1.0	15±1.6	15±2.8	13±1.7

S : Lambs grazing OWLD pastures.
SCo : Lambs grazing OWLD pastures fertilized with Co ($CoSO_4$,1 kg/ha) in 1980, 1981 & 1982.
SCO+ : Lambs grazing OWLD pastures fertilized with Co (1 kg/ha) in 1980, 1981, 1982, 1985 & 1986.
SColick : Lambs grazing OWLD pastures having access to Co enriched salt lick.
H : Lambs grazing control pastures.
HCo : Lambs grazing control pastures fertilized with Co (2 kg/ha) in 1986.
HColick : Lambs grazing control pastures having access to Co enriched salt lick.

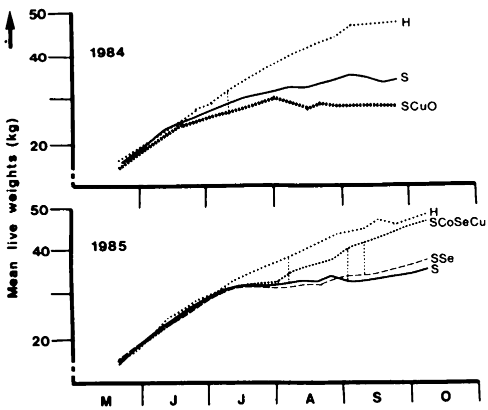

Figure 2. Mean weekly live weights (kg) in groups of lambs throughout grazing. The initial point of significant difference ($p < 0.05$) between groups are indicated by broken vertical lines. For explanation of group symbols, see Tables 1–3. Number of lambs within each group (n) was 24 within the H group, and 6 within the other groups, except the SCoSeCu group where n = 5.

severely affected than the untreated S lambs. All were thin and weak throughout August-September, with eye discharge, and 2 were icteric. The SCoSeCu lambs appeared normal. The SSe lambs did not differ from the untreated S lambs (*Ulvund & Pestalozzi* 1990a).

Dosing with CuO significantly elevated serum Cu in August-September when all individual values were above 19 µmol/l (Fig. 1). Dosing with CoSeCure kept mean serum Cu on a level like that of B_{12} treated lambs (Table 1). CuO dosing otherwise resulted in similar clinical pathology as that seen in the S lambs (*Ulvund* 1990a), but changes were more pronounced. During the later part of grazing, mean packed cell volume (PCV) was reduced to 25 %, as compared to 32 % for the untreated S lambs, mean plasma glucose was below 3.3 mmol/l, serum iron (SI) above 43 µmol/l and total cholesterol was

Table 3. Mean (± sd) serum glutamate dehydrogenase (GLDH, U/L), plasma vitamin B_{12} (pmol/l) and methyl malonic acid (MMA, µmol/l) in 5 lambs dosed at pasture outlet (may 15, 1984) with copper oxide needles (SCuO).

	Dates of blood sampling					
	May 15	May 28	June 12	July 9	Aug. 13	Sept. 25
GLDH	6±7	41±29	47±32	43±29	102±92	48±53
B_{12}	301±147	301±147	81±16	47±10	411±153	98±22
MMA	1.0±0.6	6.0±2.4	21±7.6	74±45	188±102	116±62

below 1 mmol/l. Serum urea was similar to amounts in the S lambs. Mean serum glutamate dehydrogenase (GLDH) was elevated, plasma vitamin B_{12} lowered and methylmalonic acid (MMA) elevated already from June (Table 3).

In CoSeCure supplemented lambs, PCV, glucose and SI were similar to values in the Co/B_{12} supplemented ones. Serum GLDH was low (Table 1). All had sufficient B_{12} status during July-October, but 2 lambs had elevated plasma MMA in August (Table 1). The Se dosed lambs showed haematological values similar to those of the untreated S lambs (Table 1).

Discussion

A. Serum copper in OWLD lambs and Co/B_{12} supplemented lambs

Normal blood Cu in sheep may vary according to breed and haemoglobin (Hb) type (*Wiener et al.* 1974), and alterations are also associated with the onset and course of several diseases (*Corrigall et al.* 1976). In this examination, breed and Hb type were evenly distributed within the groups, and the lambs and various controls were subject to regular clinical examination as well as examination at slaughter or autopsy.

Our lambs with OWLD most often had elevated serum Cu in the earlier phase of the disease, i. e. during July-August, as compared with the Co/B_{12} supplemented lambs. Variation in serum Cu was greater during the later phase (September-October), when amounts might be lowered. One lamb which died early of OWLD in July 1981, had a serum Cu concentration of 49 µmol/l. In 1985, when serum Cu in the S lamb was low during July-August, growth was better than during other years, and plasma vitamin B_{12} was higher, and MMA lower as well (*Ulvund & Pestalozzi* 1990a, *Ulvund* 1990a). *Sutherland et al.* (1979) also found that mean plasma Cu was higher in lambs with acute OWLD, while it was lower in the chronic form.

The elevated serum Cu seen in H lambs some years, and also the lowering effects of Co supplementation, correlate well with a concomitant subclinical and simple B_{12} deficiency recorded in these lambs (*Ulvund* 1990b). There are very few earlier reports on this. In Co deficient sheep, *MacPherson et al.* (1976) found that mean serum Cu was about 16 µmol/l, while it was below 14 µmol/l when the sheep were Co sufficient. Six steers fed a diet low in both Co and Cu developed Co deficiency in 6 to 10 months, but failed to develop Cu deficiency (*MacPherson et al.* 1973). Mean plasma Cu increased from 11 to 13 µmol/l during the first 3 months of that experiment, but decreased thereafter.

Our results may indicate that OWLD lambs either have increased intestinal absorption or increased release of Cu from the liver to the blood as compared with Co/B_{12} sufficient lambs. As erythrocyte Cu was not examined, a decreased ability of erythrocytes to take up Cu cannot be excluded. The results indicate that B_{12} deficiency, and OWLD, may conceal a marginal/deficient Cu condition. The lower serum Cu seen in some OWLD lambs during late summer may indicate depletion of the liver stores.

B. Copper and selenium supplementation

Studies of coast disease in Australia showed that supplementation with Cu, as well as with Co, was necessary for successful treatment (*Marston et al.* 1938). *Hannam et al.* (1980), however, who conducted their experiments on Co deficiency in lambs on a property near the site where *Marston et al.* made their investigations of coast disease, obtained no significant effect of Cu on live weight (lw) gain.

A growth response to Cu has been found in experimental Cu deficiency in lambs (*Howell* 1968), and studies from Scotland in lambs grazing hill pastures improved by liming and reseeding have also shown that growth can be improved by Cu supplementation (*Whitelaw et al.* 1977, 1979, *Suttle et al.* 1984, Suttle 1986). When CuO needles (2 g) were given as a single dose to 3–5 weeks old lambs, they were 3.3 kg heavier than the undosed at weaning (*Whitelaw et al.* 1983).

Mitchell et al. (1982) obtained no effect of Cu treatment on lw gain in lambs with OWLD. The fact that Cu dosing worsened the OWLD condition in our case and caused icterus in 2 lambs, may in fact indicate that OWLD lambs are more sensitive to Cu intakes. The elevation of serum Cu after dosing with CuO needles was larger than that seen after similar dosing of 5 weeks old lambs in Scotland (*Whitelaw et al.* 1980). In the 2 icteric lambs, serum Cu was higher during June-September (overall mean 23 µmol/l) than in the other 3 SCuO lambs (overall mean 18 µmol/l), as were GLDH and MMA amounts. Elevated serum GLDH indicating hepatic damage was in fact detected 2 weeks before rise of serum Cu above 19 µmol/l. Haemoglobinemia was not seen in these lambs, but plasma was yellow in August-September. The 3 others within the group had red plasma in September. Sheep on marginal Co intakes are more susceptible to Se poisoning than sheep on adequate Co (*Gardiner* 1966a), but similar mechanisms have not earlier been reported for Cu.

Intakes of plants containing alkaloids (*Heliotropium europaeum*) may cause liver damage in such a way that the liver retains Cu, increasing the susceptibility to Cu poisoning (*Seaman* 1987). In connection with liver damage due to lupinosis, increased serum Cu has been found (*Gardiner* 1966b). Although the lupins were deficient in Cu, higher morbidity and mortality rates were found when the lambs were supplemented with Cu. Mean serum Cu was not higher in the Cu supplemented sheep than in the sheep not exposed to Cu, but liver Cu was significantly higher.

The lamb which had no CoSeCu pellet in the forestomacs at slaughter, is worth mentioning in this respect. This lamb had very high liver Cu (307 mg/kg wet weight), indicating that the pellet had been dissolved and absorbed. It showed reduced growth from mid July on, and in October it was 11 kg lighter than the others within the SCoSeCu group. Serum Cu was between 8.8 µmol/l and 18 µmol/l during June-October, while serum GLDH was elevated from mid July on (41–80 U/L). Plasma B_{12} was low (< 150 pmol/l) throughout June-August, and plasma MMA increased from 1 µmol/l in June to 6 in October, all values indicating liver damage, B_{12} deficiency, and Cu toxicity. Dissolution and absorption of glass boluses have not been reported by others.

Lambs which develop OWLD show signs of liver damage at an earlier stage of disease (*Ulvund* 1990a). The damage may perhaps render the liver more vulnerable to Cu, resulting in Cu accumulation in the liver when Cu is dosed.

Live weight (lw) increases up to several kg have been found in lambs dosed with selenium as compared with undosed (*Robertson & During* 1961, *Blaxter* 1963). Growth response to a combined Co and Se deficiency has also been obtained (*McLean et al.* 1959, *Hartley et al.* 1959, *Andrews et al.* 1964), and a Se and Cu interaction has been reported (*Hill et al.* 1969). In lambs with OWLD, however, *Mitchell et al.* (1982) found no effect of Se dosing. The lack of growth response to Se in our lambs therefore correlates with their findings.

The results from our investigation showed that dosing with soluble glass pellets containing Co, Se and Cu prevented OWLD. Lw increase started 4–5 weeks after dosing, and the growth rate was similar to that obtained by Co supplementation or B_{12} treatment, and signs of liver damage were not observed. The glass pellet was developed for use in sheep by *Telfer et al.* (1983) and *Knott et al.* (1985), and *Care et al.* (1985) showed that the 17 g pellet provided sufficient Co, Se and Cu to lambs from application at 5–6 weeks of age until slaughter at 5 months of age. In lambs at risk to Co and Se deficiency, *Ellis et al.* (1987) obtained a significant lw response, similar to the response obtained by B_{12} dosing. *Driver et al.* (1986) found the pellets effective in treatment of Cu deficient lambs.

In our case, serum Cu was not particularly elevated in the SCoSeCu lambs, as compared with the untreated or Se treated lambs. This is in accordance with the findings of *Allen et al.* (1984) in lambs on summer pasture. The effect of CoSeCure dosing on plasma B_{12} appeared 3 weeks after dosing, and values were significantly elevated for at least 2 months. According to *Ellis et al.* (1987), dosing with CoSeCure maintained sufficient plasma B_{12} for more than 4 months in lambs at risk to Co and Se deficiency, while *Millar et al.* (1988) found a significant effect on serum B_{12} 12 months after dosing lambs on Se deficient, Co/Cu adequate pastures.

In conclusion, OWLD lambs had higher serum Cu than Co/B_{12} supplemented lambs on the same pastures, and although OWLD grass was low in Cu contents, dosing with Cu worsened the clinical disease and aggravated clinical pathology.

References

Allen WM, Sansom BF, Gleed PT, Mallinsom CB, Drake CF: Boluses of controlled release glass for supplementing ruminants with copper. Vet. Rec. 1984, *115*, 55–57.

Andrews ED, Grant AB, Stephenson BJ: Weight responses of sheep to cobalt and selenium in relation to vitamin B_{12} and selenium concentrations in liver and kidney. N. Z. J. agric. Res. 1964, *7*, 17–27.

Blaxter KL: The effect of selenium administration on the growth and health of sheep on Scottish farms. Brit. J. Nutr. 1963, *17*, 105–115.

Care AD, Anderson PJB, Illingworth DV, Zervas G, Telfer SB: The effect of soluble-glass on the copper, cobalt and selenium status of Suffolk Cross lambs. In: Mills CF, Bremner I, Chesters JK (eds.): Trace elements in Man and Animals. TEMA-5. Proc. 5th int. Symp. on trace elements in man and animals, Aberdeen 1984, CAB, London 1985, p. 717–719.

Corrigall W, Dalgarno AC, Ewen LA, Williams RB: Modulation of plasma copper and zinc concentrations by disease states in ruminants. Vet. Rec. 1976, *99*, 396–397.

Driver PM, Eames C, Telfer SB: Efficacy of soluble glass boluses containing copper, cobalt and selenium in store lambs. In: Proc. 6th int. Conf. on production disease in farm animals, Belfast 1986, 108–111.

Ellis NJS, Shallow M, Judson GJ: Weight gains of lambs treated with a soluble glass bullet containing cobalt, selenium and copper. Aust. vet. J. 1987, *64,* 93–94.

Gardiner MR: Chronic selenium toxicity studies in sheep. Aust. vet. J. 1966a, *42,* 442–448.

Gardiner MR: Mineral metabolism in sheep lupinosis. J. comp. Path. 1966b, *76,* 107–120.

Hannam RJ, Judson GJ, Reuter DJ, McLaren LD, McFarlane JD: Effect of vitamin B_{12} injections on the growth of young merino sheep. Aust. J. agric. Res. 1980, *31,* 347–355.

Hartley WJ, Drake C, Grant AB: Selenium and animal health. N. Z. J. agric. 1959, *99,* 259–264.

Hill MK, Walker SD, Taylor AG: Effects of marginal deficiences of copper and selenium on growth and productivity of sheep. N. Z. J. agric. Res. 1969, *12,* 261–270.

Howell J McC: The effect of experimental copper deficiency on growth, reproduction and haemopoiesis in the sheep. Vet. Rec. 1968, *83,* 226–227.

Knott P, Algar B, Zervas G, Telfer SB: Glass – a medium for providing animals with supplementary trace elements. In: Mills CF, Bremner I, Chesters JK (eds.): Trace elements in man and animals. TEMA-5. Proc. 5th int. Symp. on trace elements in man and animals, Aberdeen 1984. CAB, London 1985, p. 708–714.

Lee HJ: Cobalt and copper deficiencies affecting sheep in South Australia. J. Dep. Agric. S. Aust. 1951, *54,* 475–532.

Lee HJ: Trace elements in animal production. In: Nicholas DJD, Egan AR (eds.): Trace elements in soil-plant-animal systems. Academic Press, London 1975, p. 39–54.

MacPherson A, Moon FE, Voss RC: Some effects of feeding young steers on a diet deficient in both cobalt and copper. Brit. vet. J. 1973, *129,* 414–426.

MacPherson A, Moon FE, Voss RC: Biochemical aspects of cobalt deficiency in sheep with special reference to vitamin status and a possible involvement in the eatiology of cerebral necrosis. Brit. vet. J. 1976, *132, 294–308.*

Marston HR, Thomas RG, Murnane D, Lines EWL, McDonald IW, Moore HO, Bull LB: Studies on coast disease of sheep in South Australia. Commonwealth Scientific and Industrial Res. Org., Melbourne 1938 (Bull. no. 113).

McLean JW, Thompson CG, Claxton JH: Growth responses to selenium in lambs. N. Z. vet. J. 1959, *7,* 47–52.

Millar KR, Meads Wj, Albyt AT, Scahill BG, Sheppard AD: The retention and efficacy of soluble glass boluses for providing selenium, cobalt and copper to sheep. N. Z. vet. J. 1988, *36,* 11–14.

Mitchell PJ, McOrist S, Thomas KW, McCausland IP: White liver disease of sheep. Aust. vet. J. 1982, *58,* 181–184.

Robertson TG, During C: Live weight responses to selenium in lambs, but few responses to cobalt. N. Z. J. Agric. 1961, *103,* 306–310.

Schwan O, Jacobsson SO, Frank A, Rudby-Martin L, Petersson LR: Cobalt and copper deficiency in Swedish landrace pelt sheep. Application of diagnosis in flock-related deficiency diseases. J. vet. Med. A, 1987, *34,* 709–718.

Seaman JT: Pyrrolizidine alkaloid poisoning of sheep in New South Wales. Aust. vet. J. 1987, *64,* 164–167.

Sutherland RJ, Cordes DO, Carthew GC: Ovine white liver disease – an hepatic dysfunction associated with B_{12} deficiency. N. Z. vet. J. 1979, *27,* 227–232.

Suttle NF, Jones DG, Woolliams JA, Woolliams C, Wiener G: Growth responses to copper and selenium in lambs of different breeds on improved hill pastures. Proc. Nutr. Soc. 1984, *43,* 103 A.

Suttle NF: Copper deficiency in ruminants; recent developments. Vet. Rec. 1986, *119,* 519–522.

Telfer SB, Zervas G, Carlos G: Curing or preventing deficiencies in copper, cobalt and se-

lenium in cattle and sheep using tracerglass. Canad. J. anim. Sci. 1984, *64*, 243–235.
Ulvund MJ: Ovine white-liwer disease (OWLD). Vitamin B_{12} and methylmalonic acid (MMA) estimations in blood. Acta vet. scand. 1990a, *31*, 267–275.
Ulvund MJ: Ovine white-liver disease (OWLD). Changes in blood chemistry. Acta vet. scand. 1990b, *31*, 277–286.
Ulvund MJ, Pestalozzi M: Ovine white-liver disease (OWLD) in Norway: Clinical symptoms and preventive measures. Acta vet. scand. 1990a, *31*, 53–62.
Ulvund MJ, Pestalozzi M: Ovine white-liver disease (OWLD). Botanical and chemical composition of pasture grass. Acta vet. scand. 1990b, *31*, 257–265.
Whitelaw A, Armstrong RH, Evans CC, Fawcett AR: An investigation into copper deficiency in young lambs on an improved hill pasture. Vet. Rec. 1977, *101*, 229–230.
Whitelaw A, Armstrong RH, Evans CC, Fawcett AR: A study of the effects of copper deficiency in Scottish blackface lambs on improved hill pasture. Vet. Rec. 1979, *104*, 455–460.
Whitelaw A, Armstrong RH, Evans CC, Fawcett AR, Russell AJF: Effects of oral administration of copper oxide needles to hypocupraemic sheep. Vet. Rec. 1980, *107*, 87–88.
Whitelaw A, Russell AJF, Armstrong RH, Evans CC, Fawcett AR, MacDonald AJ: Use of cupric oxide needles in the prophylaxis of induced copper deficiency in lambs grazing improved hill pastures. Vet. Rec. 1983, *112*, 382–384.
Wiener G, Hall JG, Hayter S, Field AC, Suttle NF: Relationships between haemoglobin type and copper concentrations in whole blood and its components in sheep of different breeds. Anim. Prod. 1974, *19*, 291–299.

Sammendrag

Kvitleversjuke (kobolt/vitamin B_{12} mangel) hos lam. Serum kopper og effekt av dosering med kopper og selen.

Serum kopper var som regel høyere hos lam med kvitleversjuke (OWLD) enn hos dem som fikk tilskudd av kobolt eller vitamin B_{12}. Til tross for att graset på sjukdomsbeitene var kopperfattig ble sjukdomstilstanden forverret når lam på disse beitene ble dosert med kopper, og forandringene i blodbildet ble forsterket. Dosering med selen hadde ingen virkning på sjukdommen. Dosering med en kombinasjon av kobolt, selen og kopper resulterte i normal tilvekst, og normale forhold i blodbildet. Kontrollama viste stigning i serum kopper når de var subklinisk Co/B_{12} deficitte.

(Received January 27, 1989; accepted October 9, 1989).

Reprints may be requested from: Martha J. Ulvund, State Veterinary Research Station for Small Ruminants, Høyland, P. O. Box 264, N-4301 Sandnes, Norway.