Zeitschrift: Schweizer Archiv für Tierheilkunde SAT : die Fachzeitschrift für Tierärztinnen und Tierärzte = Archives Suisses de Médecine Vétérinaire ASMV : la revue professionnelle des vétérinaires

Herausgeber: Gesellschaft Schweizer Tierärztinnen und Tierärzte

Band: 130 (1988)

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DOI: https://doi.org/10.5169/seals-593301

Schweiz. Arch. Tierheilk. *130*, 657–672, 1988

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Toxicology of fungicides: Effects of 270 days administration of Zinc Ethylene-bis-Dithiocarbamate in Friesian cattle

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Zinc ethylenebisdithiocarbamate (Zineb) and other dithiocarbamates (DTC) are still largely employed in agriculture to control a variety of fungal pathogens of fruits, vegetables, crops and grapes. Although the acute toxicity of these compounds is generally low (1), their biological effects include antifertility, teratogenic and mutagenic effects, as they can also affect the immune and the hematopoietic systems [see Borin et al. (2) for references]. Furthermore, DTC may give rise to metabolic products such as ethylenebisisothiocyanato-sulfide (EBIS), ethylenethiourea (ETU) and carbon disulfide which, in turn, possess a wide range of toxic actions (3). However, thyroid effects are by far the most known pathologic effects associated with DTC exposure and have been investigated in several animal species (4, 5) including, as far as Zineb is concerned, rats (6), rabbits (7) and chickens (8).

In recent years, there has been a tendency to increase the number of sprayings with DTC in agriculture and up to 20 sprayings per year have been reported (9). Half concentration times for Zineb of 14 and 23 days were respectively measured on leaves and soil (10). In the light of these reports one may reasonably expect that Zineb can enter the food chain and contaminate many foodstuffs intended for human and animal nutrition. This hypothesis has been supported by a number of investigations in which DTC residues have been detected in thyroid glands from both aborted bovine foetuses (11) and regularly slaughtered cattle (Nebbia et al., unpublished results). In spite of that, there is a lack of information concerning the toxic effects of Zineb on cattle. More to the point, the question arises whether the chronic exposure to low amounts of the fungicide, as might occur in the field, is capable of impairing the normal physiological conditions of cattle. Therefore, a series of experiments have been undertaken to monitor the thyroid function and to investigate possible sites of extrathyroidal effects in Friesian calves that have been chronically exposed to Zineb.

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[2] Lavoro eseguito in parte nell'ambito del piano finalizzato IPRA del CNR, sottoprogetto n°1, pubblicazione n°1806 ed in parte nell'ambito dell'unità operativa n°8 del gruppo scienze veterinarie del CNR.

[3] Part of this work has been presented at the 28th Congress of the European Society of Toxicology, Strasbourg, 17–19 september 1987 and a brief report will be published in the proceedings of the Congress.

Material and methods

Twenty-three male, clinically healthy Friesian calves (age 4 months) were purchased from a local breeder, weighed and housed in individual manure-pack pens in a suitable cowshed. Corn silage, complete mixed feed for weaning and tap water were freely available. Hay and forage crops were also added throughout the experiment. Samples of food were periodically analyzed for DTC residues (12) to avoid Zineb overdosage. After an acclimatization period of one month, the calves were randomly assigned to three experimental groups as follows: control (7 animals), 4 mg Zineb/kg bw/day (10 animals) and 40 mg Zineb/kg bw/day (6 animals). Zineb (technical grade, 92% pure) was a gift from Farmoplant (Milano, Italia) and contained 0.25% ETU (Dr. Gaidano, personal communication).

The lower Zineb dosage was assumed to be approximately the amount of fungicide which is likely to be ingested daily by cattle grazing on pastures close to treated areas or consuming contaminated feed. Zineb was added to the mixed feed and treated calves were daily fed amounts of this mixture required to deliver the desired dosage, taking in account weight increase too.

Weight gain was checked monthly, while clinical behavior was constantly monitored.

Blood was taken by venipuncture with Vacutainers prior to starting the trial (d 0), at 30 day intervals throughout the experiment and at slaughter. Serum samples were analyzed for triiodothyronine (T3) and thyroxine (T4) concentrations by a radioimmunological method using commercial kits (Spac-T3 and Spac-T4, Mallinkrodt). An attempt to quantify the thyroid stimulating hormone (TSH) by the same method gave inconsistent results.

Hematological and clinical chemical studies were also performed. Hematological parameters included packed cell volume (PCV), hemoglobin (Hb), erythrocyte count, total and differential white cells counts which were determined by standard laboratory procedures. Clinical chemical parameters included γ-glutamyltranspeptidase (GGT), aspartate aminotransferase (ASAT), alanine aminotransferase (ALAT), sorbitol dehydrogenase (SDH), glutamyc dehydrogenase (GLDH), alkaline phosphatase (ALP) and cholesterol. All these parameters were assayed by commercial kits (Boehringer, Mannheim).

The treatment lasted 270 days. Four animals from the 4 mg/kg group, however, were continued on Zineb and treated for a total of 600 days. Therefore, 4 bulls from the control group were sacrificed 600 days after the beginning of the trial (Table 1). Data concerning these animals will be the subject of a further paper.

Table 1 Plan of the experiment

Zineb treatment (mg/kg bw/day)	Animals[1] on treatment	Animals killed after 270 days[2]	Animals killed after 600 days
None	7	3	4
4	10	6	4
40	6	6	-

[1] Number of animals to be considered for hematological, clinico-chemical and hormonal parameters.

[2] Number of animals to be considered for organ weight comparisons and histopathological results.

At the scheduled time, animals were deprived of food overnight, stunned by captive bolt pistol and exsanguinated. They were subjected to a complete necropsy and the major organs were removed and weighed. Representative samples of brain, lung, small intestine, cecum, colon, heart,

thymus, spleen, liver, kidney, testes, thyroid, adrenal, pancreas and skeletal muscle (quadriceps femoralis) were fixed in neutral buffered 10% formalin. Routine sections were prepared from paraffin embedded tissue and stained with hematoxylin and eosin (HE).

Immediately after killing, portions of thyroid, liver and kidney were also fixed in 2.5% glutaraldehyde in 0.1 M cacodylate buffer pH 7.4, post fixed in osmium tetroxide 0.1%, dehydrated, embedded and stained as usual.

Where appropriate, Student's t-test was used for statistical comparisons.

Results

Clinical signs

The overall clinicopathological findings in this study suggest a marked dose-response difference in cattle to the toxic effects of Zineb.

Unlike the group at lower dosage, in which no appreciable clinical signs were noted, a significant reduction in body weight gain soon became evident in the 40 mg/kg group. At the end of the exposure period the total weight gain in this group was reduced by about 26% when compared to control animals (Fig. 1). Calves receiving 40 mg/kg showed also an «unthrifty» appearance and their skin became locally dry and scaly. No signs suggestive of gastro-enteric involvement such as bloat or diarrhea, or neurological signs were recorded at any time.

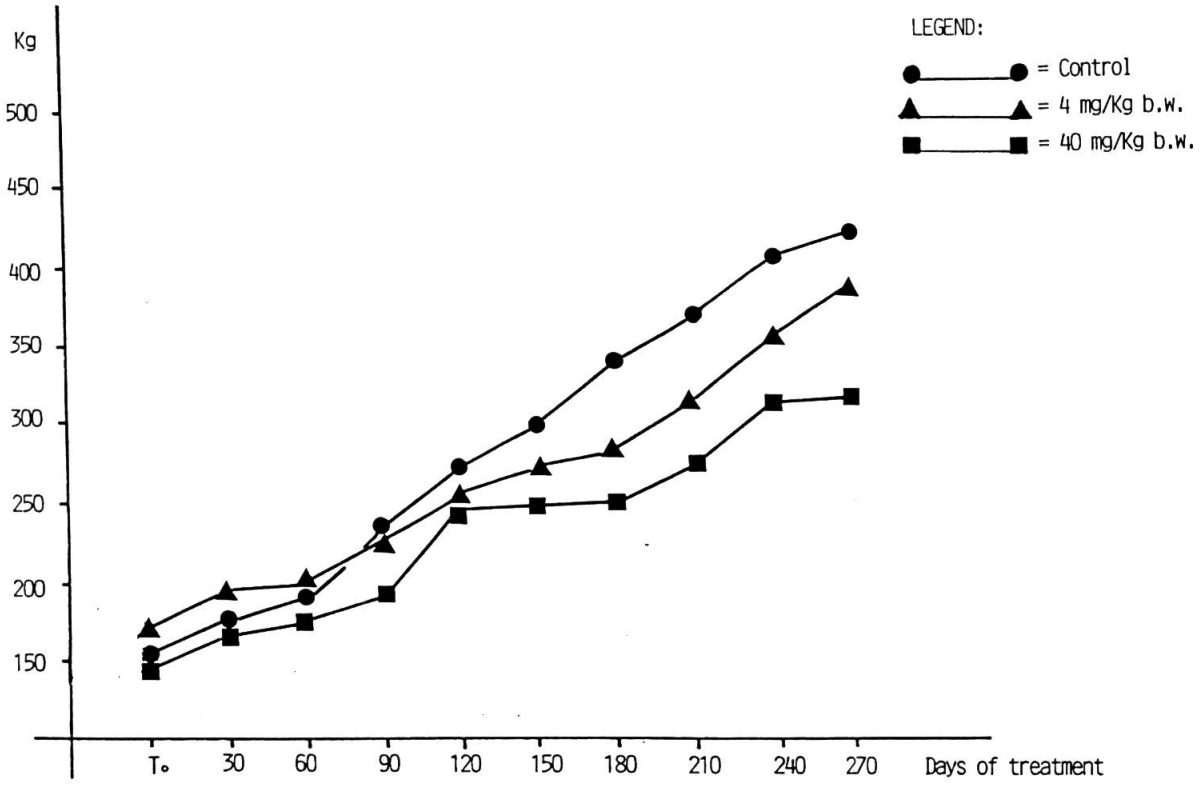


Fig. 1 Changes in body weight (mean values) after 270 days Zineb administration to Friesian cattle. Number of animals as indicated in Table 1.

Hematological and clinical chemical parameters

None of the tested hematological and clinical chemical parameters from the 4 mg/kg group differed significantly from controls. By contrast, a statistically significant decrease in PCV ($P<0.05$) and Hb ($P<0.05$) were evident in the second half of the trial in the group at higher dosage (Table 2), along with a not significant fall in the erythrocyte number (data not shown). The most prominent change in serum chemistry was an increase of GGT (up to 4.3 fold, fig. 2), which was not paralleled by a comparable rise in GLDH, SDH and ASAT (data not shown).

Table 2 Effects of the chronic administration of Zineb on PCV and Hemoglobin in Friesian cattle

Exposure period	Control	4 mg/kg bw/day	40 mg/kg bw/day
	PCV (%)		
Pre dosing	29.6±0.5	29.8±0.7	28.3±0.5
0– 90 days	30.5±1.8	30.4±1.4	30.6±1.1
90–180 days	27.3±2.1	29.4±1.9	24.6±1.1*
180–270 days	29.2±4.4	30.1±3.5	25.7±2.9
	Hemoglobin (g/dl)		
Pre dosing	9.5±0.5	9.9±0.8	9.7±0.1
0– 90 days	10.3±0.8	10.4±0.4	9.3±0.6
90–180 days	9.1±0.3	9.5±0.8	8.1±0.6**
180–270 days	9.5±1.3	9.9±0.9	7.9±0.4*

Number of animals as indicated in Table 1. Values are the means ± s. d. of four determinations for each 90 day period. Significantly different from control $P<0.05$* $P<0.01$**

Thyroid hormones

Zineb treatment affected serum T3 and T4 to a different extent according to the dosage level (Table 3).

In the 4 mg/kg group a significant decrease of both T3 and T4 occurred only in the first part of the trial (days 0–90, $P<0.01$). Both hormone levels showed thereafter a trend to rise toward the control values. Conversely, a marked decline of T4 characterized all the duration of the trial in the group fed with the higher Zineb level. Interestingly, no accompanying decrease of T3 was observed in this group. This led to a marked elevation of the T3/T4 ratio (Fig. 3).

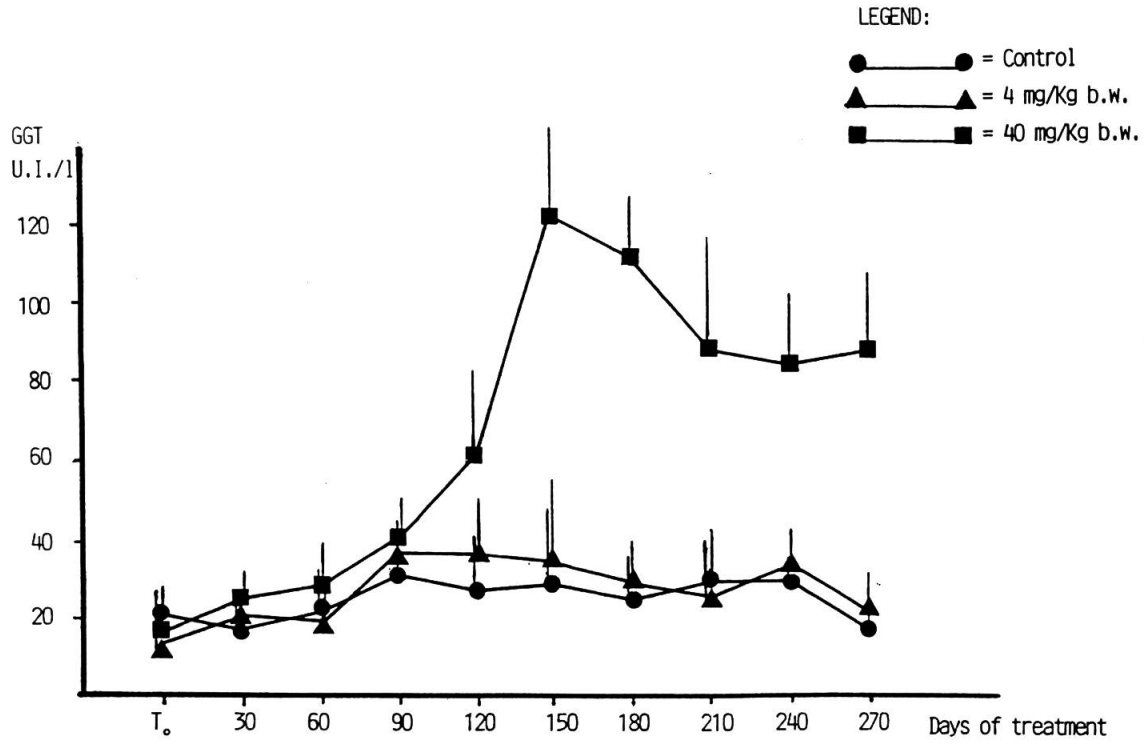


Fig. 2 Graph showing the progressive increase of serum GGT in cattle exposed to 40 mg Zineb/kg bw/day. Number of animals as indicated in Table 1. Values are means ± s. d.

Table 3 Changes of Serum T3 and T4 in cattle after the chronic administration of Zineb

Exposure period	Control	4 mg/kg bw/day	40 mg/kg bw/day
	T4 (ug/dl)		
Pre dosing	3.61±0.68	3.42±0.85	2.91±0.63
0– 90 days	5.70±1.06	3.57±1.07**	2.87±0.67***
90–180 days	8.21±1.84	6.34±1.29	4.22±2.08**
180–270 days	5.78±1.37	4.97±0.91	1.63±0.89***
	T3 (ng/dl)		
Pre dosing	172±21	166±18	152±41
0– 90 days	207±19	156±24**	186±55
90–180 days	199±19	167±38	184±33
180–270 days	163±18	142±20	172±38

Number of animals as indicated in Table 1. Values are the means ± s. d. of four determinations for each 90 days period. Significantly different from control $P<0.01$** $P<0.001$***

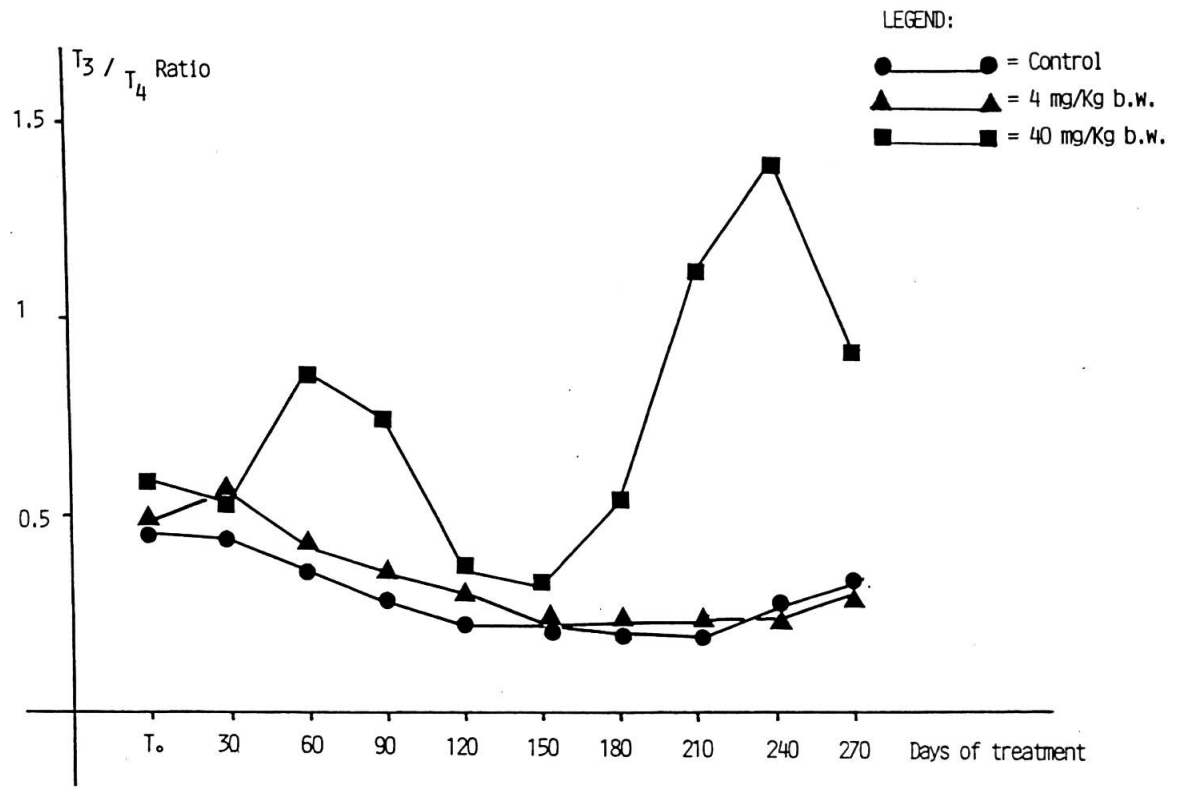


Fig. 3 Effects of Zineb exposure on T3/T4 ratio in cattle.

Gross pathology

At necropsy, the only remarkable alterations consisted in liver and thyroid enlargement concerning the 40 mg/kg group ($P<0.05$). There was also a marked reduction in both the absolute ($P<0.001$) and relative weight of the testes ($P<0.05$). No other evident macroscopic alterations were found in either experimental groups, except for a mild hydropericardium probably not related with Zineb administration.

Control animals did not show appreciable gross lesions.

Table 4 Organ weights of cattle fed Zineb for 270 days

Organ	Control	4 mg/kg bw/day	40 mg/kg bw/day
Thyroid			
wt, g	31.6±4.8	28.2±5.7	53.2±18.6
% bw (10^3)	7.5±0.8	7.3±1.8	17.1± 4.9*
Liver			
wt, kg	6.5±0.7	6.7±0.7	7.3± 1.2
% bw	1.5±0.2	1.7±0.2	2.2± 0.5*
Testes			
wt, g	390±52	340±70	208± 40***
% bw (10^2)	9.3±1.6	8.9±1.8	6.5± 1.6*

Number of animals as indicated in Table 1. Values are means ± s. d. Significantly different from control $P<0.05$* $P<0.001$***

Histopathological and ultrastructural changes

Remarkable histologic changes were found in the thyroid, liver, testes, central nervous system (CNS) and myocardium of treated animals, while sections from controls were considered free of significant alterations.

Thyroid

All treated cattle showed thyroid changes characterized by enlarged follicles filled with colloid and lined by either polygonal or flat epithelium with the prevalence of the flat form (Fig. 4). These functional alterations appeared to be more marked in the 40 mg/kg treated group where the amount of colloid suggests a picture of colloid struma. In some cases, there was also rupture of the follicular walls (Fig. 5). No foci of hyperplasia involving the follicular epithelium were detected.

Ultrastructural observation revealed the presence of numerous enlargements of the smooth endoplasmic reticulum (S. E. R.) filled with homogeneous material in both polygonal and flat cells (Fig. 6). The latter often showed nuclear pycnosis.

Liver

In both treated groups the lesions were characterized by a diffuse foamy appearance of hepatocytes. A few scattered cells with eosinophilic cytoplasm, usually grouped to form columns, were also noted (Fig. 7).

At the electron microscopic level, the hepatocytes with a foamy appearance presented diffuse cytoplasmic storage of glycogen (Fig. 8). On the other hand, the eosinophilic cells were characterized by intense proliferation of S. E. R. tubules (Fig. 9). The biliary ducts were not apparently involved.

Fig. 4 Thyroid from 4 mg/kg treated calves group. The follicles are filled with colloid and show flat epitelium. (H. E. – 100 ×).

Fig. 5 Thyroid from 40 mg/kg treated calves group. More severe lesions leading to colloid struma are observed in this group. The follicle wall is very thin and often broken. (H. E. – 100 ×).

Fig. 6 Thyroid from 40 mg/kg treated calves group. Ultrastructural appearance of a flat follicular epithelial cell, showing marked vacuolization and cromatin condensation. (E. M. – medium magnification).

Fig. 7 Liver from 40 mg/kg treated calves group. Foamy appearance of hepatocytes with some aspects of cells with eosinophilic cytoplasm (arrows) (H. E. – 400 ×).

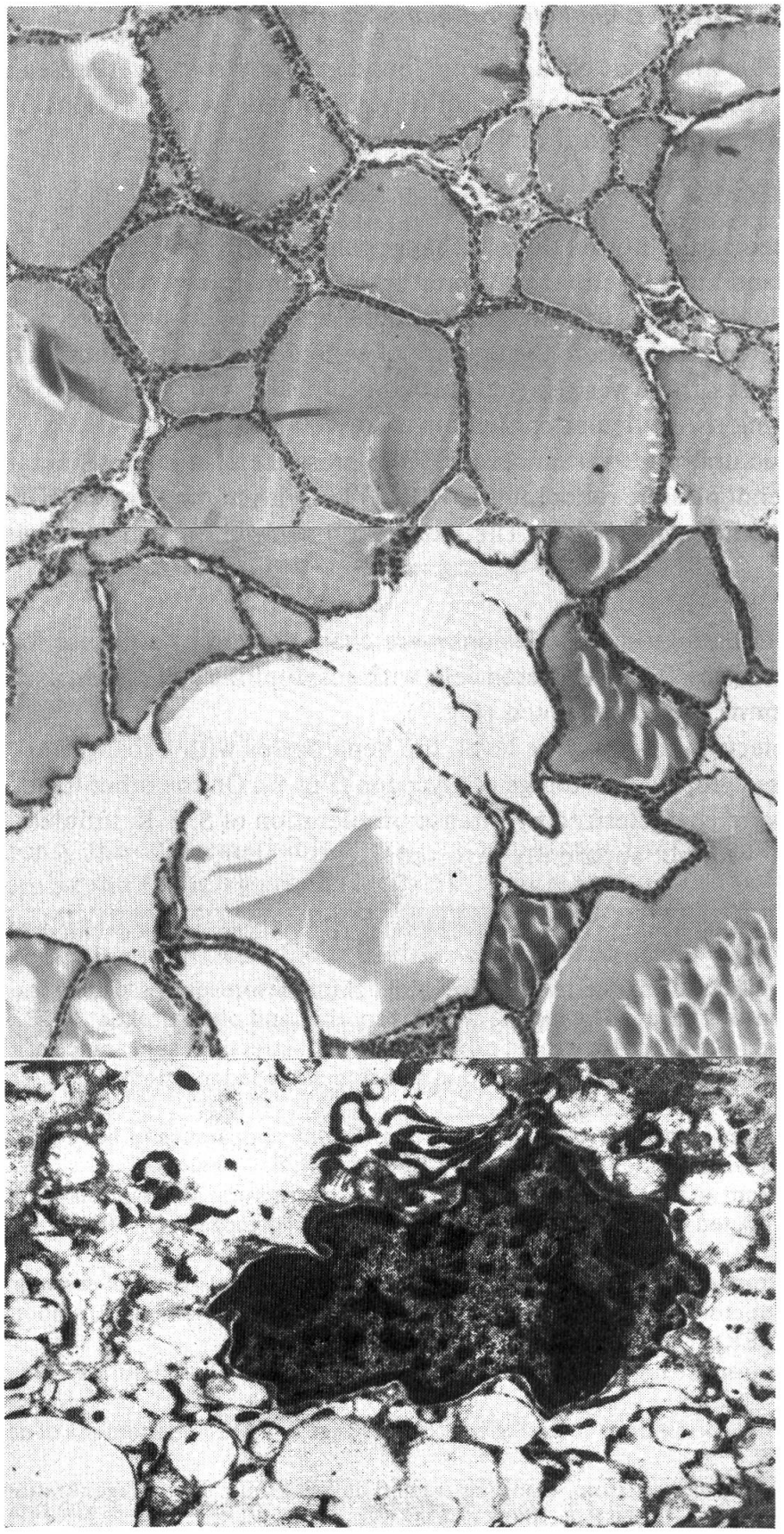
Fig. 8 Liver from 40 mg/kg treated calves group. Ultrastructural observation reveals that foamy appearance is related to diffuse intracytoplasmic storage of glycogen (GL) (E. M. – medium magnification).

Fig. 9 Liver from 40 mg/kg treated calves group. Ultrastructural aspect of eosinophilic cells detected at light microscopic level. Note the proliferation of tubular elements of smooth endoplasmic reticulum (SER) (E. M. – medium magnification).

Fig. 10 Testis from 40 mg/kg treated calves group. Note lacking of mature sperm cells (H. E. – 400 ×).

Fig. 11 Cerebral cortex from 40 mg/kg treated calves group. Mild phenomena of neuronophagia (H. E. – 400 ×).

Fig. 12 Cerebellar cortex from 40 mg/kg treated calves group. Note degeneration of Purkinje cells and neuronophagia (H. E. – 400 ×).



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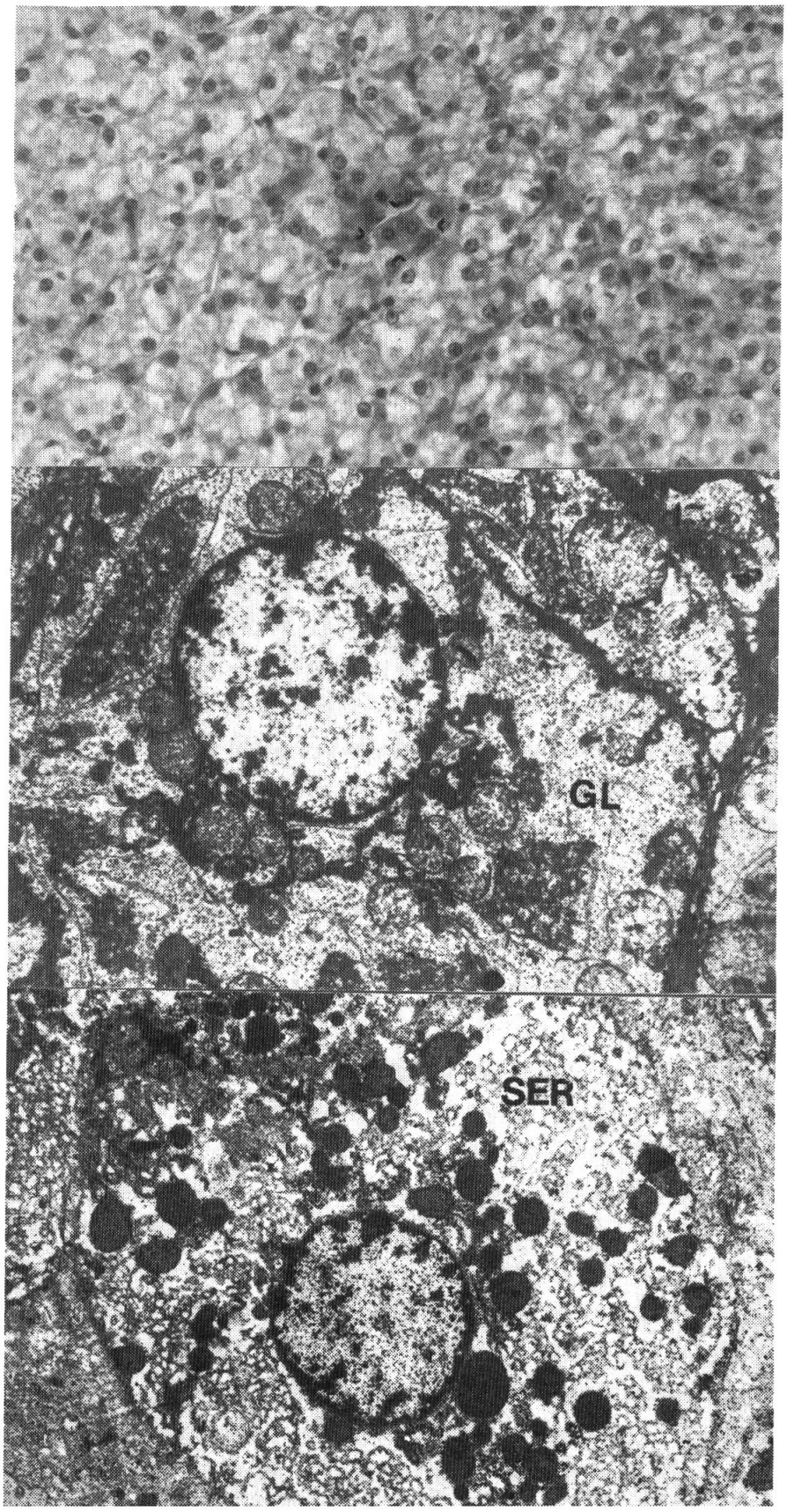

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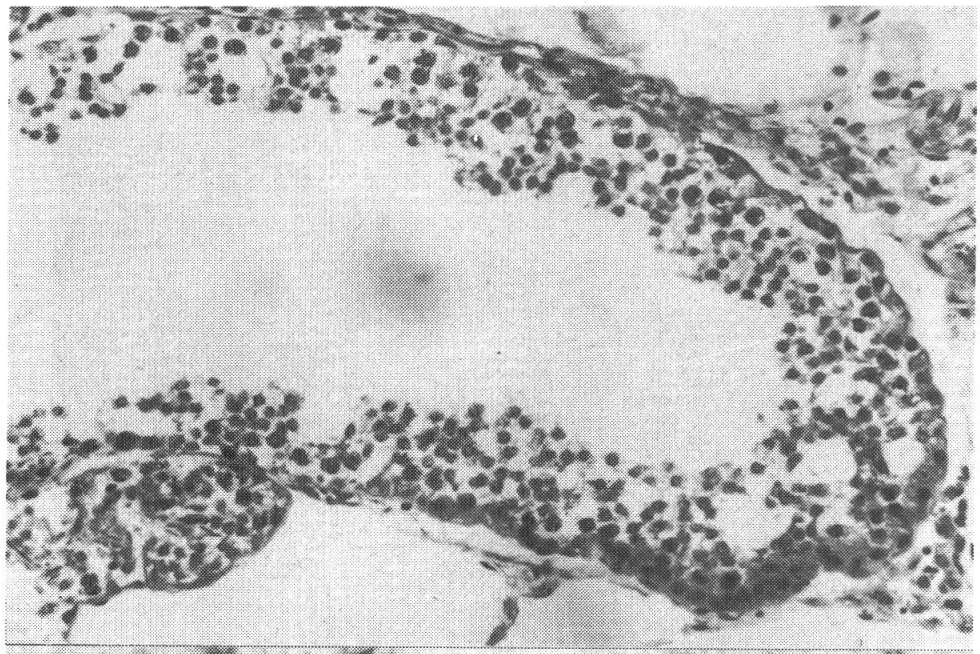

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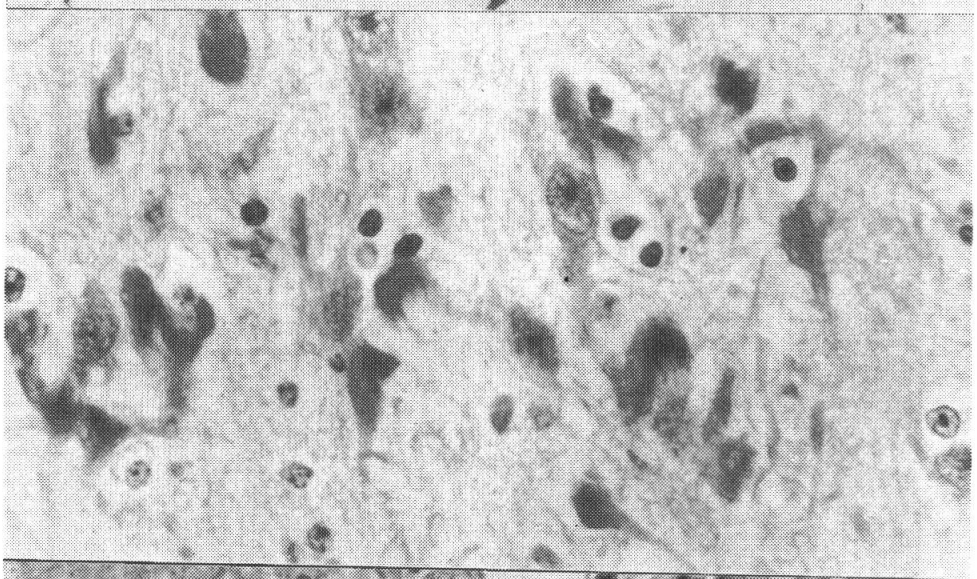

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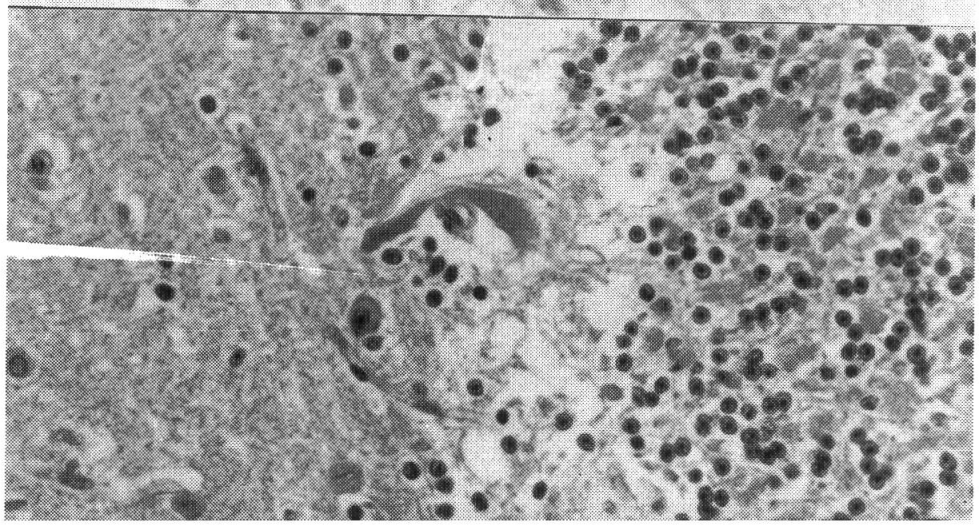

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Testes

At the lower Zineb dosage damaged tubules were scattered among normal ones showing aspermia and rarefaction of spermatids and spermatocytes. Similar alterations were observed in the 40 mg/kg group although the extent of the damage appeared considerably higher, some tubules being lined only by spermatogonia (Fig. 10).

SNC

Mild foci of neuronophagia were constantly detected among neurons of cerebral cortex (Fig. 11) and cerebellar Purkinje cells (Fig. 12) in all the treated cattle regardless of the dosage group.

Myocardium

Anitschkow cells were observed in both treated groups without any further morphological change.

Discussion

Reduced weight gain and feed conversion as well as harsh coat have been reported in laboratory and farm animals during chronic Zineb toxicosis (13). Bloat and gastrointestinal signs which have been described by others in ruminants (14) were never observed. In our study, the impaired general health in the 40 mg/kg group may be related with the decrease in Hb concentration. Zineb and some of its metabolites have been shown to inhibit δ-aminolevulinic acid synthetase, one of the key enzymes of the heme biosynthesis (15).

The depression of the thyroid function may also have contributed to some extent in determining the poor performance of the 40 mg/kg treated animals. Thyroid histological and ultrastructural changes in this group suggest an initial stage of colloid struma. Interestingly, foci of proliferation of follicular cells within the lumen were apparently lacking. Colloid struma accompanied by foci of epithelial hyperplasia was seen both in chickens (16, 17) or in rabbits (7) chronically exposed to the fungicide. By contrast, various degrees of follicular cell hypertrophia along with the formation of numerous microfollicles were characteristically observed in rats after long-term oral Zineb administration (6).

Zineb treatment (40 mg/kg) brought about a marked elevation of the serum T3/T4 ratio by markedly decreasing T4 levels without substantially affecting T3 levels. The mechanism underlying this effect is not fully understood. For instance, Zineb could act peripherally by enhancing the rate of extrathyroidal deiodination of T4, a metabolic process which accounts largely for the production of serum T3 (18). On the other hand, the marked elevation of serum T3/T4 may reflect a preferential secretion of T3 relative to T4 due to the well known action of thionamide drugs directed against coupling of iodinated tyrosyl residues (19). It is interesting to remark that by the chronic administration of either Zineb or ETU to rats, only the latter was found to elicit serum T3–T4 changes comparable to those reported in the present experiment (20).

Mild thyroid changes were detectable at the end of the exposure period in the group at lower dosage. Thyroid involvement, as assessed by thyroid hormone measurements, appeared to be restricted only to the first part of the treatment. In the light of these results, it is possible that Zineb administration under the experimental conditions of the 4 mg/kg group was not sufficient to overcome the natural mechanisms of adaptation of the thyroid gland.

Zineb exposure caused detectable liver changes in both treated groups. A correct evaluation of the severity of the lesions found in the 4 mg/kg group as compared to those detected in the group receiving higher Zineb doses should include a morphometric measurement. Nonetheless, liver from the 40 mg/kg group appeared to be involved to a somewhat greater extent. This is in agreement with the observed rise in serum GGT, a useful indicator of non necrotic hepatic damage (21). Abnormal storage of glycogen in hepatic cells may be essentially due to either hyperglycemia, as in diabetes mellitus (22), or to the toxic inhibition of glycogen degradation (23), both resulting in the typical picture of plant – like cells. In our case, since blood glucose was not measured, neither pathogenetic mechanism should be excluded. When considering the second hypothesis, however, it should be noted that a reduction in the circulating levels of thyroid hormones may depress the rate of glycogenolysis, leading therefore to an abnormal accumulation of glycogen (24). The scattered foci of S. E. R. proliferation in the hepatic cells should be regarded with concern because of the possible interactions with the microsomal monooxygenases regulating the oxidative metabolism of xenobiotics. Details concerning these particular aspects have been reported elsewhere (25).

Zineb administration resulted in testicular damage which was most evident in the 40 mg/kg group. Testicular injury has also been reported in rats (26) and cocks (8) after prolonged feeding with the fungicide. Although sperm analysis was not performed in our study, it should be noted that Zineb was found to significantly impair the quality of the semen from experimentally exposed rams (27). Antigonadal effects of DTC appear to be the result of a decreased output of the Luteinizing Hormone Releasing Factor (28). Nonetheless, it should not be overlooked that «in vitro» incubations of bovine testis homogenates with Zineb brought about a potent inhibition of LDH-X, a key enzyme of the spermatogenesis (29).

CNS changes as a response to Zineb administration have been previously described in rats (30) and neurological signs have been reported in man following acute exposure to the fungicide (31). A paralytic syndrome was also described in rabbits after prolonged treatment with the fungicide (7). Although overt neurological signs were not recorded in our study, it should be emphasized that foci of neuronophagia were constantly found in all treated animals. Moreover, since CNS lesions were detected in both cerebral and cerebellar cortex, possible neurobehavioral effects might be elicited in species belonging to a higher zoological scale when accidentally exposed to the fungicide.

Finally, the zinc moiety of the fungicide may have played a role in determining the toxic syndrome described in the present paper. A severe outbreak of zinc toxicosis with high mortality has been recently reported in preruminant calves. Clinical signs began to

appear when calves each were being fed approximately 1.5 to 2.0 g of zinc per day (as zinc sulphate) and exposed to a cumulative zinc intake of 42 to 70 g (32). In our experiment, a comparable zinc daily intake was reached in the 40 mg/kg group as early as the beginning of the trial, resulting at the end of the treatment in a cumulative zinc intake of approximately 600 g. Despite this, none of the clinicopathological signs referable to zinc toxicosis were ever observed. A possible explanation for this finding could reside in the poor absorption of the fungicide (33) and the more advanced stage of development of the forestomachs in our animals compared to the abovementioned preruminant calves. Additionally, the absorbed zinc ethylenebisdithiocarbamate might not be as active as zinc sulphate in releasing zinc ions. A specific study has been already planned which will deal with the modification of the trace element concentrations in blood and organs brought about by Zineb administration.

In conclusion, the prolonged exposure of cattle to relatively low amounts of Zineb proved to affect the thyroid function in a dose-dependent manner. Zineb displayed also extrathyroidal effects consisting in hepatic and testicular injury which was clearly evident in animals ingesting as little as 4 mg of fungicide per kg bw per day. Since exposures of this order of magnitude are likely to occur in the field, it is concluded that every effort should be made to avoid the contamination of foodstuffs with Zineb and related compounds.

Summary

Zinc-ethylene-bisdithiocarbamate (Zineb) was added to the diet and administered to Friesian calves at the rate of zero, 4 and 40 mg/kg/day for 270 days. Marked dose-response thyroid effects were observed resulting in thyroid enlargement, depressed function and colloid struma. Livers from both treated groups showed glycogenosis and scattered foci of proliferation of the smooth endoplasmic reticulum, although considerable changes in γ-glutamyltranspeptidase activity were noted only in the 40 mg/kg group.

Testes showed dose-related weight reduction and germ cell depletion.

Results indicate that chronic Zineb exposure, even at levels as low as 4 mg/kg bw/day may impair.thyroid function and also exert a number of extrathyroid effects.

Riassunto

E'stato condotto un esperimento di tossicità cronica con l'etilenbisditiocarbamato di zinco (Zineb) in bovini Frisoni allo scopo di valutarne l'azione a livello tiroideo e possibili effetti extratiroidei. Il fungicida è stato somministrato nel mangime alle dosi giornaliere di zero, 4 e 40 mg/kg p. v./giorno per 270 giorni.

Sono stati osservati effetti tiroidei dose-dipendenti consistenti in aumento di peso della ghiandola, diminuita funzionalità e struma colloide.

In entrambi i gruppi si è riscontrato un interessamento epatico consistente in glicogenosi e focolai di proliferazione del reticolo endoplasmatico liscio. Un significativo aumento dell'attività sierica della γ-glutamiltranspeptidasi è stato tuttavia osservato soltanto nel gruppo trattato con 40 mg/kg.

Sono state infine osservate lesioni testicolari dose-dipendenti variabili da una riduzione degli elementi germinali maturi a completa aspermia.

Nel complesso, l'esposizione cronica di bovini Frisoni anche a piccole dosi di Zineb è in grado sia di deprimere l'attività tiroidea sia di esercitare effetti extra-tiroidei.

Zusammenfassung

Zinkaethylen-bisdithiocarbamat (Zineb) wurde zum Futter von schwarzbunten Kälbern in der Menge von 0, 4 und 40 mg/kg KG/Tag beigefügt und während 270 Tagen verabreicht. Deutliche dosisabhängige, thyreotrope Wirkungen wurden festgestellt, die in Grössenzunahme der Schilddrüse, Funktionsverminderung und Kolloidstruma bestanden. Die Lebern beider Behandlungsgruppen zeigten Glykogenose und verstreute Herde von Proliferation des glatten endoplasmatischen Retikulums, obschon bemerkenswerte Veränderungen der γ-Glutamyltranspeptidaseaktivität nur in der 40-mg/kg-Gruppe festzustellen waren.

Die Testikel zeigten dosisabhängige Gewichtsverminderung und Keimzellverarmung.

Diese Resultate zeigen, dass chronische Zineb-Aufnahme – selbst in so geringen Mengen wie 4 mg/kg KG/Tag – die Schilddrüsenfunktion behindern und eine Anzahl extrathyreoidaler Wirkungen verursachen kann.

Résumé

Le bisdithiocarbamate-éthylène de Zinc (Zineb) a été additionné à l'aliment de veaux de race tâchetée noire à des doses de 0 mg, 4 mg et 40 mg/kg poids vif/par jour et administré pendant 270 jours. Des effets thyréotropes dépendant significativement de la dose ont été constatés. Ils se composaient d'une augmentation de volume de la thyroïde, d'une diminution de sa fonction et d'un goitre colloïdale. Les foies des 2 groupes traités présentaient une glycogénose et des foyers disséminés de prolifération du réticulum endoplasmique lisse, bien que des modifications de l'activité du transpeptidase γ-glutamylique n'ont été constatées que dans le groupe à 40 mg/kg poids vif.

Les testicules montraient suivant la dose utilisée une diminution de leurs poids et un appauvrissement en cellules germinales.

Ces résultats démontrent qu'une consommation chronique de Zineb – même à des doses si faibles comme 4 mg/kg poids vif/par jour – inhibent la fonction de la thyroïde et peut causer un nombre d'effets extrathyroïdiens.

Literature

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Registration of manuscript: April 18th 1988

BUCHBESPRECHUNG

Parasitology in Focus. Facts and Trends. Herausgegeben von Heinz Mehlhorn. Berlin, Heidelberg, usw.: Springer-Verlag 1988. XVII + 924 Seiten, 1998 Abbildungen auf 399 Tafeln, 119 Tabellen, Kunstleinen, Preis DM 298.–.

Zweck des Werkes ist es, wie Herr Mehlhorn im Vorwort schreibt, eine umfassende Übersicht über Geleistetes und über die Arbeitsrichtungen in der veterinär- und humanmedizinischen Parasitologie zu geben. Nur verstärkte Anstrengungen im Kampf gegen die Parasiten können verhindern, dass uns in Zukunft Probleme mit der menschlichen Gesundheit und bei der Nahrungsmittelproduktion überwältigen.

Das Buch besteht aus 22 Kapiteln unterschiedlicher Länge, die von insgesamt 29 Autoren bearbeitet wurden. Die ersten 148 Seiten umfassen den Abschnitt «Kreisläufe» (H. Mehlhorn, V. Walldorf), behandeln also die Biologie der Protozoen und Metazoen. Um das originelle Konzept des Bandes vorzustellen, seien in der Folge die übrigen Kapitelüberschriften aufgeführt: Verhalten und Parasitismus (E. Curio), Morphologie (H. Mehlhorn et al.), Vermehrung (H. Mehlhorn et al.), Genetik der Parasiten (W. Kunz, W. P. Voigt), intraspezifische Variation und Epidemiologie (R. C. A. Thompson), Ernährung und Stoffwechsel (P. Köhler, W. P. Voigt), Wirtfindung (W. Haas, W. P. Voigt), Parasiten und Hormone (K. D. Spindler), klinische und pathologische Hauptbefunde bei parasitären Infektionen der Haustiere (J. Vercruysse et al.), wichtige pathologische Auswirkungen bei parasitären Infektionen des Menschen (J. K. Frenkel et al.), klinisches Bild und Pathologie bei parasitären Infektionen des menschlichen Auges (J. Grüntzig), geomedizinische Aspekte der Parasitologie (E. Hinz), Immunantwort des Wirtes (S. Lloyd, E. J. L. Soulsby), genetische Kontrolle der Immunität gegenüber Wurminfektionen (D. Wakelin), Serologie und immundiagnostische Methoden (G. Weiland), Gefrierkonservierung von Parasiten (E. R. James), in vitro-Kultur bestimmter parasitärer Protozoen (B. Enders), Parasiten und Vakzinierung (H. G. Heidrich), Chemotherapie und andere Bekämpfungsmassnahmen bei parasitären Krankheiten der Haustiere und des Menschen (W. Raether), Resistenz (K. T. Harinasuta, D. Bunnag), Strategien beim Kampf gegen Parasiten (W. H. Wernsdorfer). Diese Themen entsprechen den wichtigsten Arbeitsgebieten der parasitologischen Forschung von heute.

Da die einzelnen Texte von bestausgewiesenen Fachleuten verfasst wurden, entstand ein Gesamtwerk von höchstem Niveau. Sorgfältige Redaktion, ausgezeichnete Qualität der Abbildungen sowie hervorragende drucktechnische Ausstattung tragen zusätzlich zum Wert des Bandes bei – und fordern natürlich ihren Preis.

Es war eine faszinierende Idee, den gegenwärtigen Stand des Wissens in der Parasitologie einmal in einer Gesamtschau darzustellen. An diesem Fach interessierte Tierärzte, Ärzte und Biologen werden beim Studium des ganzen Werkes oder einzelner Teilabschnitte eine ungeheure Fülle von Informationen finden und – wenn sie daran mit einem gewissen «esprit préparé» herangehen – nützliche Anregungen für die eigene Arbeit bekommen.

B. Hörning, Bern