Copper poisoning in a dairy herd fed a mineral supplement

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Abstract

Copper poisoning in a dairy herd resulted in the death of 9 of 63 (14%) adult Holstein cows. Clinical signs were acute anorexia, weakness, mental dullness, poor pupillary light reflexes, and scant nasal discharge. These were followed by recumbency, chocolate-colored blood, jaundice, and death. Four animals exhibited signs of hyperesthesia and/or rumen stasis prior to death. At necropsy there was generalized icterus of body tissues, with the liver appearing orange and the kidneys dark blue. Histologically, there was accumulation of hemosiderin in Kupffer cells, and severe to moderate hepatocellular necrosis in all cases. Ammonium molybdate added to the ration, combined with the cessation of mineral supplementation, arrested the outbreak.

These cases illustrate significant mortality, due to copper poisoning, in adult cattle fed a low-dose mineral dietary supplement for over two years. Dietary copper intake of the herd (on a dry matter basis) was 37.5 mg/kg for lactating cows and 22.6 mg/kg for dry cows.

Résumé

Empoisonnement au cuivre dans un troupeau de bovins laitiers nourrit avec un supplément de minéraux

Un empoisonnement au cuivre a causé la mort de 9 (14%) vaches d'un troupeau de bovins holstein. Les signes cliniques présentés étaient de l'anorexie, de la faiblesse, de la confusion mentale, un réflexe pupillaire diminué et un écoulement nasal peu abondant. Ces symptômes ont progressé en décubitus, de l'ictère, du sang de couleur chocolat et finalement la mort. Quatre animaux ont présenté de l'hyperesthésie et/ou une stase du rumen précédant la mort. La nécropsie a mise en évidence un ictère généralisé des tissus, un foie de couleur orangée et des reins bleu foncé. Les coupes histologiques présentaient une accumulation d'hémosidérine dans les cellules de kupffer et une nécrose hépatocellulaire de modérée à sévère. La situation a été corrigée en ajoutant du molybdate d'ammonium à la ration alimentaire et en omettant le supplément de minéraux.

Ces cas démontrent un taux de mortalité significatif du à un empoisonnement au cuivre. Ces vaches adultes avaient été alimentées avec un ajout d'une faible quantité d'un supplément de minéraux pour une période de 2 ans. Les vaches en lactation recevaient 37.5 mg/kg de cuivre sur une base de matières sèches alors que les vaches taries recevaient 22.6 mg/kg.

(Traduit par Dr Thérèse Lanthier)

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Introduction

Chronic copper poisoning has rarely been reported in adult dairy cattle (1-4). The usual observation is an acute disease of young cattle and calves after short-term ingestion of excessive dietary copper. However, Stogdale (2) reported a herd outbreak of chronic copper poisoning in which the cows were fed over 11 g copper sulfate daily, with three deaths occurring after six months of supplementation. Perrin *et al* (4) also reported significant mortality in a large herd of dairy cows after long-term, erroneous copper supplementation of at least 328 mg/kg in the ration.

Adult cattle are thought to be quite resistant to copper poisoning because surplus dietary copper is excreted; the great majority is eliminated in the feces and much less in the urine (5-6). However, cattle will continue to absorb excess dietary copper, as there is no control mechanism to restrict its absorption (6). Alimentary copper that is retained is primarily concentrated in the liver (5). Unlike sheep and calves, cows have a reserve capacity for hepatic storage of copper. Nonetheless, as the maximum storage level is approached, rapid hepatic cell death occurs, and copper is released into the circulation (7). Red blood cells are hemolyzed in the presence of high blood copper levels and hemoglobin is converted to methemoglobin (3,6-7). Hemoglobinuria may also occur (8). The destruction of red cells on such a massive scale leads to generalized icterus. This destruction also leads to anemia that, combined with the depletion of hemoglobin concentration in the remaining erythrocytes, produces a drop in oxygen-carrying potential and eventual asphyxia (7). During the accu-

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mulation phase, necrosis of hepatocytes occurs, inhibiting the excretion of hepatic copper via the bile (7). Various environmental or nutritional stressors may be involved in the hepatic liberation of copper (5,6,8).

Shortly after hypercupremia develops, cows will demonstrate signs of jaundice, anemia, hemoglobinuria, anorexia, nasal discharge, abdominal pain, and frequent recumbency. Cows usually die from 12–72 hours after the onset of clinical signs (3,7,8).

Other dietary metals interact with copper. Molybdenum has a sparing effect on surplus dietary copper. In fact, molybdenum can promote removal of hepatic copper (9). High levels of dietary sulfur are protective of copper overload, and will increase copper excretion by the liver and kidney (9).

I report herein an episode of deaths of nine adult dairy cows over a three-month period. I will present evidence to indicate that the toxicity was probably due to chronic, low-dose copper supplementation.

History

Three nonlactating cows from an eastern Ontario herd of grade and registered Holsteins died of obscure causes in the fall of 1983. The farmer also reported that his remaining cows had experienced poor milk production and general unthriftiness since June of 1983. This herd started on a new mineral supplementation and feeding program in May of 1981. A custom mineral was delivered in bags to the farm and the total ration was balanced and formulated, based on feedstuff analysis, by the mineral vendor. Each feedstuff and the mineral had been analyzed independently, on behalf of the vendor, by the New York State College of Veterinary Medicine. The herd has previously been fed about 100–140 g of a standard proprietary mineral top-dressed on the roughage. The mineral supplement and feed ration consumed at the time of the first deaths had been fed continuously since June of 1983. The mineral was top-dressed on the roughage fed to each cow according to the ration calculated and provided by the mineral supplier (Table 1).

Treatment for indigestion and poor production had been attempted by the previous veterinarian, with no success. After three deaths in the fall of 1983, the farmer considered the possibility of poisoning by a suspicious plant, long present in his pasture and stored hay. A sample of the plant was submitted by the farmer to Agriculture Canada. It was identified as *Rumex crispus*, commonly known as curled dock. This plant may be associated with oxalate poisoning (8), and this possibility was considered early in the episode.

Table 1. Ration formulation for a dairy herd with copper poisoning

A. Daily ration fed to cows at time of disease outbreak[a,b]

Dry cows:
- 5.9 kg dry hay providing 0.1209 g Cu
- 5.5 kg corn silage providing 0.0385 g Cu
- 0.46 kg haylage providing 0.0031 g Cu
- 0.085 kg custom mineral providing 0.1081 g Cu
- 12.0 kg dry matter providing total Cu in daily ration of 0.27 g or 22.6 mg/kg

Lactating cows:
- 2.4 kg dry hay providing 0.0483 g Cu
- 4.6 kg haylage providing 0.0303 g Cu
- 1.6 kg soya providing 0.0212 g Cu
- 6.5 kg high-moisture corn providing 0.0110 g Cu
- 5.1 kg corn silage providing 0.0360 g Cu
- 0.74 kg custom mineral providing 0.6415 g Cu
- 21.0 kg dry matter providing total Cu in daily ration of 0.79 g or 37.5 mg/kg

B. Copper content of water collected at the barn tap[c]
0.04 mg/L

[a]Analyses of foodstuffs and mineral performed by Ontario Ministry of Agriculture and Food (OMAF), Toxicology Laboratory, Guelph, Ontario except for soya, performed by New York State College of Veterinary Medicine
[b]Feedstuff amounts stated on dry weight basis
[c]Analyzed by Ontario Ministry of the Environment

Clinical findings and treatment

Case 1 — On January 3, 1984 I was called to the farm to examine a dry, pregnant, last-trimester cow. The farmer reported that the cow was nervous and anorexic. Clinical examination showed dilated pupils, firm feces, static rumen, and normal vital signs. Based on clinical signs, a provisional diagnosis of mild hypocalcemia and indigestion was made, and the cow was treated with 500 mL calcium (Calcium Borogluconate, M.T.C. Pharmaceuticals, Cambridge, Ontario), administered intravenously. A mixture of 9 L water, 2 L mineral oil (Light Mineral Oil, M.T.C. Pharmaceuticals), 200 g of powdered electrolyte (Life-Guard, Norden Laboratories, now SmithKline Beecham Animal Health, Mississauga, Ontario), and 200 g of a magnesium oxide and *nux vomica* proprietary carminative and ruminatoric product (Oxamin powder, M.T.C. Pharmaceuticals) was infused into the rumen. The cow improved and was eating well on the next day.

On January 16, the cow was again very ill showing signs similar to the first visit, so more aggressive calcium therapy was instituted. This time, the cow received 1000 mL calcium gluconate (Calcium Borogluconate, M.T.C. Pharmaceuticals) and 500 mL of 50% dextrose (Dextrose 50%, M.T.C. Pharmaceuticals) intravenously. Serum samples were submitted to the Ontario Ministry of Agriculture and Food (OMAF) for biochemistry and whole blood for hematology (Table 2). In spite of this treatment, the cow died on January 18. At this time, frozen liver and feed samples were submitted directly to the Guelph Toxicology Laboratory of OMAF for toxicological analysis. With the knowledge of *Rumex crispus* contamination of the feed, and the history of cows showing signs often associated with hypocalcemia, oxalate poisoning was the first diagnosis considered.

In mid-January of 1984, toxicological analysis of hay and haylage by the OMAF Toxicology Laboratory in Guelph indicated no contamination with oxalates.

In light of the fact that a dock species was identified as a forage contaminant, the possibility of nitrate poisoning was also investigated. The OMAF Toxicology Laboratory found 389 mg/kg nitrate and 4.0 mg/kg nitrite in the haylage (on a wet weight basis). Forages containing over 1.0% nitrate can produce toxicity (11); the levels found in this case were

Table 2. Summary of laboratory results for cows with copper poisoning

Case number	1	2	3	4	5	6	Normal[a]
Postmortem copper levels							
Kidney copper (mg/kg)[b]	159	588	964	ND	464	200	20 (10)
Liver copper (mg/kg)[b]	1926	1236	2179	ND	1854	1796	100–400 (9)
Serum profile results[c]							
Calcium (mmol/L)	3.7	1.7	2.0	4.1	2.2	ND	2.0–2.7
Phosphorus (mmol/L)	ND	ND	0.83	2.29	0.25	ND	1.19–2.69
Magnesium (mmol/L)	ND	ND	1.23	1.75	1.00	ND	0.79–1.19
Urea (mmol/L)	6.1	ND	ND	ND	9.8	ND	1.8–7.1
Creatinine (μmol/L)	68	ND	130	146	109	ND	60–120
Glucose (mmol/L)	1.2	1.8	8.4	6.7	4.0	ND	2.6–4.3
Tot. bilirubin (μmol/L)	13	30	165	92	224	ND	0–9
Conj. bilirubin (μmol/L)	1	7	69	40	18	ND	0–5
Free bilirubin (μmol/L)	11	23	96	52	205	ND	0–5
CK (CPK) (U/L)	399	465	178	2798[d]	477	ND	40–200
AST (SGOT) (U/L)	109	>4000	2320	ND	2210	ND	39–72
GGT (U/L)	19	159	217	126	130	ND	0–5

[a]Kidney and liver copper levels are referenced; profile normals are OMAF levels
[b]Normal and reported levels on a dry weight basis, except normal kidney levels reported on a wet weight basis
[c]Obtained antemortem and before treatment
[d]Cow was recumbent
ND = not done

very much lower (less than 0.04%), thus eliminating nitrate poisoning as a cause of illness.

After a second cow (case 2) died on the same day, the entire carcass of cow 1 was submitted for necropsy to the OMAF Laboratory in Kemptville, Ontario.

Case 2 — This cow was acutely ill on January 17, with anorexia, static and doughy rumen, dilated pupils, poor pupillary light reflex, mental dullness, and a trace of mucous nasal discharge. This dry, five-year-old cow, was carrying a last-trimester fetus. At this time, no diagnosis had been made in case 1, so symptomatic treatment was administered similar to that given to cow 1, based on the hypothesis that these cows were dying of oxalate poisoning and its attendant hypocalcemia. The animal died late on January 18. Blood samples drawn on the day of death were submitted for biochemistry and hematology. The antemortem serum sample was later assayed for copper by the OMAF Toxicology Laboratory.

Since this was the second cow to die on the same day and the fifth in the episode, and no diagnosis had yet been made, a decision was made that the farmer would take this cow to the OMAF Pathology Laboratory in Kemptville for necropsy. A tentative diagnosis of chronic passive hepatic congestion was made by this laboratory on January 20.

Also on this date, the OMAF Toxicology Laboratory in Guelph reported that cow 2 had a serum copper of 8.2 mg/kg from the antemortem sample. We then realized that the cows had died of copper poisoning.

On January 30, the OMAF Toxicology Laboratory reported that the liver and kidney samples from these first two cases showed excessive copper. Their report confirmed that this was a case of copper toxicity, possibly on a herd level.

Concurrently, the company supplying the mineral had independently submitted samples of silage, haylage, and high-moisture corn to the Biosystematics Research Institute of Agriculture Canada, Ottawa, Ontario. On January 27, 1984 Agriculture Canada reported the presence of fungi in the feed. *Monascus ruber* van Tiegh was the only organism found in any significant amount (this was not a quantitative test). At this time, a random group of serum copper levels was run on the herd, showing several animals with high serum copper (Table 3). Blood copper levels ranged from 1.05 to 2.92 mg/kg; normal levels are considered to be 0.7 to 1.7 mg/kg (12). At this point, all dietary mineral supplementation was discontinued in an effort to prevent further hepatic copper accumulation.

Case 3 — On February 14, a dry, four-year-old cow was examined. She was recumbent and unable to rise; mucous membranes were uniformly pale yellow. This cow had normal vital signs but was dull and depressed, with static rumen and an expiratory grunt, and the blood sample taken was a chocolate-brown color. Supportive therapy consisting of 1 L sodium chloride (Sodium Chloride, Cutter Laboratories Ltd., Calgary, Alberta), 500 mL calcium (Calcium Borogluconate, M.T.C. Pharmaceuticals), and 500 mL of 50% dextrose (Dextrose 50%, M.T.C. Pharmaceuticals) was administered intravenously, but the cow died on the following day.

On Feburary 15, the Poison Control Center for Veterinarians at the University of Illinois was contacted regarding the case. They advised ammonium molybdate orally as a preventive and as a possible method of achieving copper excretion from tissues. All cows, both dry and lactating, were given 500–1000 mg of the crystalline powder (Ammonium Molybdate, BDH Chemical, Toronto, Ontario) daily as a top-dress on the feed, starting February 18, 1984. The farmer used a measuring spoon and roughly adjusted the dosage based on the cow size, but the actual amount given was usually closer to the lower end of the range.

Case 4 — On February 18, 1984 cow 4 aborted twin, eight-month fetuses, with one calf born alive. On February 20, the cow became recumbent, anorexic, and held her head laterally against her neck. She was also hyperesthetic and had dilated pupils with poor

Table 3. Serum copper and necropsy findings for cows with copper poisoning

A. Serum copper[a]

Date	1984-01-27	1984-03-04	1984-05-29
Number of cows	9	10	11
Mean (mg/kg)	1.59	1.63	0.72
SD (mg/kg)	0.59	0.76	0.15

B. Necropsy findings

Case	Diagnosis	Gross lesions	Histological lesions
Case 1	Copper toxicity, subacute hepatopathy and acute nephrosis	Yellow fat, orange liver, deep-brown renal cortex	Hepatic necrosis, portal distribution of fibrosis and biliary stasis. Severe renal cortical necrosis
Case 2	Copper toxicosis, massive peracute nephrosis	Nutmeg liver, deep brown-red kidneys. Fetus present	Coagulation necrosis of liver. Renal epithelium contained brown pigment
Case 3	Chronic copper poisoning	Generalized icterus. Fetus present	Not done
Case 4	Copper toxicity	Gun-metal blue renal cortices. Fetus present	Not done
Case 5	Chronic copper poisoning	Similar to case 4	Bile stasis and hemosiderin in Kupffer cells
Case 6	Chronic copper poisoning	Similar to case 4	Similar to case 5

[a]Obtained on three separate occasions from the same group of cows

pupillary light reflex, cold extremities, static rumen, and pale yellow mucous membranes. An antemortem blood sample was dark and red-brown. She received 500 mL of a proprietary solution containing calcium, phosphorus, magnesium and dextrose (Cal-Dextro, Ayerst Laboratories, Montreal, Quebec), and 500 mL of calcium (Calcium Borogluconate, M.T.C. Pharmaceuticals) intravenously, but died early the next day.

Case 5 — A dry, six-year-old cow died suddenly on February 25, after an illness of about 12 hours duration. The farmer reported that the cow was dull and lethargic and had cold ears. A necropsy revealed generalized icterus of all tissues, especially the mesentery and subcutaneous fat. The kidney was very dark blue, while the liver was orange-brown. Also on this date, blood samples from the same cows previously sampled were submitted for serum copper analysis to OMAF Toxicology.

Case 6 — The last cow to die in the episode became sick on February 25, 1984. She was a dry, five-year-old, had normal vital signs, was anorexic and dull, but had pink mucous membranes. In the absence of an antidote for the poisoning, palliative treatment of my own design was attempted to keep the cow alive until she could rid her system of the copper. The cow was treated intraruminally with 680 g of a propylene glycol-yeast proprietary mixture (Bovamix, Langford Incorporated, Guelph, Ontario), 100 g oral electrolytes (Life-Guard, Norden Laboratories), and 250 g magnesium sulfate (Bovotone, M.T.C. Pharmaceuticals) in water. Two days later, the cow was still anorexic and unable to rise. The animal had a very loud apex heart beat, static rumen, and yellow mucous membranes. Treatment continued with another ruminal infusion, but the animal did not respond. On the third day, a male fetus was aborted; the cow was found dead the subsequent morning.

On March 5, 1984 ammonium molybdate supplementation was discontinued because of the fear of creating copper deficiency and molybdenum toxicity in the herd. Also at this time, a new feeding program was adopted. After a complete absence of supplementary dietary mineral since late January, a new, lower-dose mineral mixture (about 140 g, compared to roughly 700 g before the outbreak) was fed to the lactating dairy cows. This was a standard mineral supplied in bags from another supplier. The new ration was the same as the previous one, except for diminution in quantity of the new mineral fed. As of September 1, 1991 no new cases of copper poisoning had been diagnosed and improvements in milk production had been experienced. The breed class average (BCA, the cow's actual production divided by the BCA standard for the breed multiplied by 100) is a measure of performance used to compare an individual cow or herd to the other cows in the national dairy herd. Based on results of a supervised milk measurement program (Ontario Dairy Herd Improvement Association), milk production rose from a herd BCA of 122 on July 11, 1984 to 134 on March 2, 1985. This level was still below average but did represent an improvement in the level of milk production. The farmer claimed that milk production increased at the start of the new mineral and feed program adopted in May 1981. This was followed by a decline in production in the last year of supplementation with the higher dose mineral, and by a cascade of events defined by ill health and ultimately deaths of mature cows.

It should be made clear that not all cows were clinically ill in this herd of 63 adult Holsteins. All affected cows were dry at the time of illness or death, but not every dry cow became sick. Though no hard data are available, the farmer estimated the dry period was about three months for both affected and normal cows.

Laboratory findings

Antemortem metabolic profile results from five of six cows showed elevations of total bilirubin varying from 13 to 224 μmol/L (see Table 2). Elevated conjugated bilirubin, y-glutamyl transferase, and aspartate aminotransferase were consistent with hepatocellular necrosis.

A group of cows was sampled on three separate occasions to determine if serum copper was declining with our treatment regime. The mean concentration of serum copper in the group decreased from 1.53 mg/kg on January 27, to 0.72 mg/kg on May 29, 1984 (Table 3). The initial concentrations were not toxic but were high normal (reference range 0.7 to 1.7 mg/kg) (12). The latter concentrations apparently reflected the marked restriction of dietary copper intake.

The cows that died had marked accumulation of copper in the liver and kidney. For example, hepatic copper concentrations varied from 1236 to 2179 mg/kg (on a dry matter basis) in the five cows necropsied. Cow 2 had a very high serum copper on the day of death (8.2 mg/kg), indicating that large-scale liberation of copper had occurred.

On March 5, 1984 two months after mineral withdrawal, the farmer consented to percutaneous liver biopsy using a True-cut needle on two surviving, lactating cows. There was 430 and 50 mg/kg copper in the liver samples from these two animals.

All feedstuffs, including the custom mineral, were assayed for copper at the OMAF Toxicology Laboratory in Guelph. The feed ration calculations reflected the actual amounts of copper found in each foodstuff.

Pathological findings

Extensive hepatocellular and renal tubular damage was seen in all necropsied cows. Patchy necrosis of the liver and accumulation of brown pigment in Kupffer cells were prominent findings. Grossly, yellowing of the fat and generalized icterus were also seen in all cows. There was a characteristic gun-metal blue to black color to the renal cortices, which occurs in copper poisoning in cows (6,8). These findings supported a diagnosis of hepatopathy caused by copper toxicity. Cow 4, which had aborted two fetuses, also had a third fetus found in the uterus at necropsy.

Necropsy findings are summarized in Table 3.

Discussion

The suggested maximum of copper in the bovine diet, according to the Canadian Feed Regulations, is 100 mg/kg (dry matter basis) (13). This episode and that reported by Perrin *et al* (4) suggest that this may be too high. This level may be acceptable for a short time, but much lower levels are often recommended for long-term feeding. Weiss *et al* (7) noted that a level of 8 mg/kg of copper in the daily ration is adequate in cattle. Auza (14) believes that 50 mg/kg is too high, quoting the Agricultural Research Council figure of 10 mg/kg of copper as a better level for cattle. In the case reported herein, the lactating herd received more than 31.8 mg/kg for over 2.5 years (Table 1). This level would lead to problems if the recommendations of Auza and Weiss are to be believed.

In a British Columbia trial, Miltimore *et al* (15) showed that Jersey steers fed cobalt-iodized salt, *ad libitum*, containing 0.5% copper (as copper sulfate) and alfalfa hay showed a statistically significant accumulation of hepatic copper. In that experiment, salt consumption averaged 35 g/head/day over 333 days, thus providing 175 mg of copper per day. This study demonstrated a maximum rate of accumulation of 343 mg/kg copper in the liver of one steer. This is equal to a rise of 1.03 mg/kg copper in the liver per day of feeding. If this information can be used as a model, and if it is assumed that all of the dietary copper is provided by the mineral supplement, then the lactating cows would accumulate 1259 mg/kg in a 333-day period (641.5 mg per day of copper was provided by the mineral in the lactating cow ration, which would translate to an accumulation rate of 3.78 mg/kg copper per day). This would result in an accumulation of 1153 mg/kg copper in the liver in the average 305-day lactation, discounting any additional copper sources in the feed. Furthermore, Miltimore *et al* (15) state that a level of 8.2 mg/kg in the ration would be sufficiently high that copper supplementation would not be recommended. The Miltimore *et al* (15) study strongly supports the idea that the copper intake in the present case was too high, and that, given the length of time for which they were fed, this intake could produce toxic levels of copper in the liver. Another Canadian source states that levels of 20 to 30 mg/kg copper in the daily ration are toxic to ruminants when fed over a long period (16).

Copper content of the feedstuffs is not the only consideration in the case reported herein. Extremely low levels of molybdenum in the feed could have resulted in the toxic accumulation of copper in the liver at this level of copper intake (6). This theory cannot be substantiated because no analysis for molybdenum was done on any feedstuff.

Trifolium subterraneum (subterranean clover) is a plant that, under favorable conditions for growth, takes up negligible molybdenum and normal to high levels of copper. If a ruminant eats this plant in sufficient quantities, copper poisoning occurs as a result of a rapid increase in hepatic copper (8,17). This has previously been reported to be a problem of sheep in Australia, but these plants are not native to Canada (1,17,18). Phytogenous, secondary copper poisoning is therefore very unlikely in this case.

Direct damage to the liver by a plant toxin must also be considered as a cause for accumulation of copper in the liver. Hepatogenous, chronic copper poisoning occurs when *Heliotropium europaeum* and certain ragworts (*Senecio* spp.) are consumed by ruminants. These plants produce hepatotoxic alkaloids that alter hepatocytes, greatly enhancing their ability to concentrate copper and thus cause chronic copper poisoning (17). Of these, a few *Senecio* spp. occur in Ontario, so a slight possibility does exist for this type of cop-

per poisoning in our case (18). A specific plant toxin was never identified, but *Rumex crispus* was found in the hay fed to the dry cows in the herd. This plant is not known to be toxic to cows, nor to cause hepatic impairment. According to the farmer, this weed had been present in the feed for at least a decade, further reducing the chances of it being the cause of the outbreak.

The farmer was also questioned about all medications given to these animals, and no other sources of copper could be identified. All cows that died were pregnant, dry, and in average body condition, and were in the period when their ingestion of copper was lowest. However, the stress of late pregnancy may have contributed to the mortality in this group. For example, cow 4 was carrying triplets, a metabolic stress that may have triggered a hemolytic crisis. It is believed by many (4,5,7,8,16) that passive accumulation of copper can occur over a long period of time. This phase ends when some stress, such as dietary change, transport, or pregnancy, initiates a cascade of metabolic events leading to acute illness and often death. Some other unknown process could also have caused hepatocellular necrosis and thus liberation of stored copper.

Fortunately, within two months of withdrawal of the supplemental mineral, and of the addition of ammonium molybdate to the ration for 18 days, no further deaths or even clinical signs were seen. Serum copper levels were significantly lowered using this method of treatment; the mean serum copper in a group of the cows dropped from 1.59 mg/kg on January 27 to 0.72 mg /kg on May 29. Also, random hepatic biopsies of two surviving herdmates yielded liver samples that had normal and low concentrations of copper of 431 and 48 mg/kg, respectively (normal is 100 to 400 mg/kg)(9). These findings suggest that the restriction of copper in the ration was beneficial. They also support the notion that high dietary intake of copper was at least part of the problem. Ammonium molybdate appeared to be a useful adjunct to the restriction of copper in the ration. In fact, only a short course of this preparation may have fairly dramatic effects on hepatic copper, and its use should be carefully monitored. The only reliable means of monitoring would be copper analysis of hepatic biopsies, as was done in this case.

Practitioners must be aware that copper poisoning can occur in adult dairy cows, especially those periparturient, and that prevention is crucial in these cases, since treatment of clinical cases is not rewarding. Careful ration formulation and mineral supplementation may be ways of preventing cases of chronic copper poisoning in adult dairy cows.

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