AN ABSTRACT OF THE THESIS OF

William Elmer Dent (Name) for the Master (Degree) in Dairy Husbandry (Major)

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The similarity of abnormal conditions as found in many foreign countries and other sections of the United States compared with those found in cattle of the Oregon Coastal Region led to nutritional studies with copper and cobalt. These abnormalities included: scours, grass tetany, acetonemia, loss of condition, depigmentation and numerous other disorders.

Cobalt deficiency which affects sheep and cattle is characterized by lack of appetite, emaciation, and loss of energy. Anemia is present at times, usually in advanced cases. Generally forages containing less than 0.07 ppm cobalt are causitive. The deficiency may be corrected by feeding the animals cobalt in the form of drenches or licks. Cobalt fertilization of pastures will also alleviate the deficiency.

Copper values in forages with less than 7-12 ppm cause abnormalities evidenced by loss of condition, rough coat, anemia in advanced cases, and low blood copper values in the animal tissues. The deficiency may be corrected by supplying copper directly to the animal using drenches or licks. Copper fertilization of pastures is also effective as a control. There are areas which have a dual deficiency of copper and cobalt.

Molybdenum in various quantities was found to cause certain disorders in cattle. These include profuse scouring, depigmentation and other disorders. If insufficient copper is ingested by the animal the molybdenum excess causes the copper to become unavailable for utilization in the animal body. Excess molybdenum affects the phosphorus utilization in the animal. Corrective measures for controlling the excess molybdenum intake are affected by raising the animal's copper intake.

Cobalt, copper deficiency and excess molybdenum symptoms may be quite erratic. These may vary from a subacute form with younger animals affected only, to an acute fatal stage. Certain long-continued feeding practices will sometimes cause deficiencies which are otherwise not noticed or non-apparent.

Although much of the evidence presented herein was not the result of carefully controlled experiments, certain beneficial results using copper and cobalt were analogous to results in other deficient areas. A similarity was found in climatic and general soil conditions of certain areas as compared to the Oregon Coastal Region.

Copper and cobalt administration to cattle in the Oregon Coastal area controlled scours in most instances. An improved coat condition was effected and color changes in the hair coat resulted when copper and cobalt were fed. The incidence of acetonemia and animals going off feed decreased with copper and cobalt administration. This indicates that there may be a beneficial effect of some nature.

Analyses for cobalt in this area show that this element is present in sufficient quantity in most instances and a cobalt deficiency generally may not be a problem except under isolated circumstances. However, the possible beneficial influence on copper utilization when cobalt is fed in conjunction with copper as experienced by various workers would indicate that cobalt should be included in mineral supplements if copper must be used in the Coastal Area.

Regions with forages having copper means of 14.2, 11.2, 11, and 10 ppm experienced copper deficiency and molybdenum excess symptoms when the molybdenum means were 4.4 and 6.5 ppm. Animals in one area had deficiency symptoms when the molybdenum ranged from 1.1 to 4.3 ppm. In the Oregon Coastal region studied a copper mean of 7.1 ppm was determined from the limited forage samples available. A molybdenum mean value of 3.5 ppm was found.

Due to the limited data and the lack of experimental controls, definite conclusions cannot be drawn. However, the beneficial response of animals to copper and cobalt in the Oregon Coastal Region as presented indicates that further work is warranted.

NUTRITIONAL STUDIES OF COPPER AND COBALT IN CATTLE IN THE OREGON COASTAL REGION

by

WILLIAM ELMER DENT

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Professor of Dairy Husbandry

In Charge of Major

Redacted for privacy

Head of Department of Dairy Husbandry

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Dean of Graduate School

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INTRODUCTION

For years there have been numerous unexplained losses from scours in the Oregon Coastal Region. Some of these losses may be accentuated by underfeeding. Diarrhea also could be the result of an increased worm infestation due to the rundown condition of animals. The presence of Johne's disease in this region has also increased the difficulty in effecting a clear cut approach to the problem and it was thought some unexplained losses where definite diagnosis had not been established could be due to this disease.

With increased emphasis placed on the use of home produced roughages, necessary in a good pasture and grass silage program, the incidence of acetonemia in the Coastal section has appeared to be on the increase. Border-line cases of cows going off feed, without the animals showing a complete acetonemia syndrome, have been numerous.

Experiments with Vitamin D supplements did not result in immediate cure of animals thought to be showing Vitamin D deficiency and general rachitic signs such as swollen leg joints, stiffness in movement and travel, roached back and poor appetite.

Where good management practices have been in vogue there has not been a clear picture of a particular deficiency. The symptoms appear to be of a border-line nature.

Abnormal conditions in cattle of the Oregon Coastal Region, as evidenced by scours, acetonemia, grass tetany, more than normal decline in milk in late lactation, decline in succeeding lactations, swelling of the leg joints in dairy cattle, and numerous other unexplained disorders, led to studies with copper and cobalt since 1949. Treatments of copper and cobalt were used on cases showing the various abnormal symptoms indicated, and presented herein are the results found when cobalt and copper were used.

Most of the experimental work in this study was not carried on under carefully controlled conditions. Due to the fact that no definite work had been attempted previously with copper and cobalt in this area, cases showing definite symptoms similar to those described by other workers in copper, cobalt deficient and excess molybdenum areas were treated as the occasion presented.

The economic losses in the Coastal Region from these abnormal conditions indicated have been estimated to be more than $250,000 annually and from present indications this figure may be too low.

REVIEW OF LITERATURE

Deficiencies of minor elements for both plants and animals have gradually expanded to the point where a very wide field is covered. These deficiencies are becoming more obvious as new areas are brought into cultivation, as agricultural production grows older, and as more efficient livestock is produced which make greater demands for better nutrition. Deficiencies or excesses of various mineral elements are not found uniformly throughout the world. They are usually found in a particular or restricted locality.

As newer knowledge has become available in the last twenty years its application has permitted others to trace out the true cause of many diseases which previously were not directly attributable to an excess or deficiency of specific trace elements. Knowledge and experience gained in some areas have helped others solve and diagnose the cause of unknown troubles in their particular areas.

The literature review is limited to cobalt, copper and molybdenum because conditions found in the Oregon Coastal Region parallel the conditions found in cobalt and copper deficient areas and excess molybdenum areas. Due to certain interrelationships of some of these minerals, the literature will be reviewed in the sequence of cobalt, copper, cobalt and copper, and molybdenum.

Cobalt Deficiencies and Diseases Attributed to Lack of Cobalt

A partial summary is presented in Table I giving the common nomenclature of the various diseases and the countries in which they are found. Abnormal and normal cobalt values of forages are presented with liver cobalt values and corrective measures.

Bush-Sickness - New Zealand

The general area is confined to the Central Plateau of the North Island and the province of Nelson in the South Island. The soil formation in one instance is related to a volcanic area which gave rise to coarse pumice soils (84, p.4), in other areas to soils of granite origin (4, p.192A), while loam soils were also affected. Loose sandy soils in certain areas are affected (84, pp.3-7). Animals are sensitive to cobalt deficiency in the following order: weaned lambs, mature sheep, calves six to eighteen months of age, and mature cattle. In 1923 the disease occuring in some areas was described as a progressive anemia accompanied by emaciation, loss of energy, and death by exhaustion when sheep were pastured in an affected area for varying lengths of time--six weeks to five months. Some areas did not show an anemic picture (5, p.305A) but the sick animals had pale skin and gums. Askew and Dixon in 1937 (8, p.708) found the kidneys of cobalt treated sheep had about six times and the gall bladder about twice the amount of cobalt compared to sick sheep.

Some areas (73, pp.95B-101B) showed a general trend of low cobalt content in the forage throughout the year. In other areas there was a seasonal fluctuation which showed a low cobalt content during the fast growing season with increases experienced during the fall and winter when growth was retarded. Also, some relationship was noted where cobalt content increased during cold weather and dry weather. The

TABLE I.

Cobalt Deficiency Summary

Disease	Country and References	Forage Analyses		Liver Analyses		Corrective Measures
		Abnormal	Normal	Abnormal	Normal	
		ppm	ppm	ppm	ppm	
"Bush-sickness" (cattle-sheep)	New Zealand 3,8,73,19,6,12	0.04-0.07	0.08-1.26	0.02-0.03	0.05- +	drench, licks top dressings
"Morton Mains" (sheep)	New Zealand 40,64,42,7,6	0.04-0.07	0.04-0.11	0.02-0.04	0.17-20.0	drench, licks top dressings
"Enzootic marasmus" (cattle-sheep)	Australia 49,50,81,100,101	0.02-0.07	0.03-0.43	0.07	0.20	drench, licks top dressings
"Pining" (cattle-sheep)	United Kingdom 30,52,86,96	0.20	0.43	----	----	drench, licks top dressings
"Grand Traverse" (cattle)	Michigan 11,65,38	below 0.07	above 0.07	----	----	salt licks
(sheep)	Canada 22,21,20	0.01-0.02	0.16	----	----	drench licks

closeness of grazing seemed to be a factor influencing the cobalt content. The closer the pasture was grazed the greater the cobalt increase. Type of plant (6, p.689) was also a factor influencing the amount of cobalt as some plants were higher in cobalt content than others grown on the same soil.

Generally the cobalt content (91, p.14) of the forage was related to the cobalt content of the soil.

Applications (19, pp.493-494) of cobalt were found to correct the "Bush-sickness" while lime when applied in some cases seemed to have a depressing effect on the uptake of cobalt (6, p.690).

Morton Mains Disease - New Zealand

The deficiency symptoms (40, p.600) for Morton Mains disease are very similar to those of "Bush-sickness" except there is no marked anemia.

Cows and calves (41, pp.343-344) did not seem to suffer in this area as sheep or bovines did in other areas. Comparison (72, pp.655-660)(64, pp.694-706) of cobalt content for soils in the "Bush-sick" area against the values in the Morton Mains soils showed the latter to be fairly well supplied with cobalt. Pasture values seemed to vary from season to season and within the season. During some years (7, pp.317-325) there was no sickness with cobalt contents running .04 parts per million to .11 parts per million[1] while other years sickness was present in the same areas with cobalt values .04 ppm

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1. Parts per million will hereafter be designated as ppm.

to .07 ppm. Cobalt uptake was benefited when limestone was applied (42, pp.1A-6A). Phosphates (84, pp.3-7)(6, pp.688-692) also gave a beneficial uptake of cobalt with cobalt and phosphate being applied simultaneously.

Enzootic Marasmus - Australia

This disease (50, pp.199-201) which occurs in cattle and sheep is of a wasting nature and is found in a district near the south coast of West Australia. In general the trouble was experienced on a sandy loam type soil while in South Australia (70, p.107) a similar condition was found in a black, friable clay soil overlying limestone.

Young cattle (49, pp.24-25) six to eighteen months of age seem to be more susceptible than mature cattle. Sheep and particularly lambs showed less resistance than cattle. The disease is prevalent throughout the year. The season of early spring and early summer when the green feed is more abundant tends to aggravate the condition. Sheep and cattle show a decreasing appetite until the animal loses condition and literally starves to death even though abundant and apparently excellent pasture is available. Lack of appetite is accompanied by an abnormal craving for bones, sticks, bark, and soil. Cows show abnormal decline in milk during lactation, difficulty in getting with calf, and sometimes abort. Wasting, a condition of progressive emaciation, in cows is often rapid, particularly after calving or abortion. Cattle and sheep die from three to twenty-four months after the first symptoms. The disease affects sheep and calves more rapidly than older cattle.

Cattle (101, p.604-605) were cured by feeding 0.3 to one milligram[2] cobalt daily while it was necessary to feed a minimum of 0.1 mg daily to sheep. No favorable results (102, pp.155-163) were obtained by copper feeding. Cobalt alone corrected the "stringy" condition of wool which appears under copper deficient conditions. Some cases did not present the low hemoglobin levels as found in other areas while showing emaciation and other symptoms. Two calves dying from enzootic marasmus (92, p.22-23) showed a high iron content in the liver, spleen, and kidneys compared with normal calves. Excessive quantities of hemosiderin were present in the affected spleens. In the case of affected sheep normal iron contents were found. Copper values in the tissues were not as high as those for normal sheep but they were higher than the values found in copper deficient sheep. The copper levels (102, p.162) for grasses in affected and unaffected areas had a mean 3.7 ppm and 9.9 ppm dry matter basis respectively. Cobalt in grasses (92, p.22) varied from .04 ppm for affected areas to 0.13 ppm for unaffected areas. The cobalt content of pastures was increased by cobalt fertilization. Cobalt deficiency had no effect on horses (103, p.199).

Filmer and Underwood (101, p.604) in 1934 discovered that certain extractions of limonite, a hydrated oxide of iron found by Aston of New Zealand (10, p.378) in 1932 to have curative properties effecting recovery of sick animals when administered orally, was not due to

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2. Milligram will hereafter be designated as mg.

its iron content. The beneficial extraction contained nickel, manganese, cobalt and zinc. Later tests (66, p.117) using pure compounds showed the effective agent was cobalt. This was the key for all future cobalt deficiency work throughout the world.

Nakuruitis - Kenya

The disease (92, p.23) is found in grazing cattle in the Nakuru district of Kenya from which the disease name is derived. Pasturing for four to six months produces a condition indicated by emaciation with marked anemia, and showing in advanced stages loss of power and coordination. The disease was seasonal, with young cattle more susceptible than older animals. Depraved appetite indicated a craving for certain local "earths". Affected cattle when removed to other unaffected areas were cured if the animals were not in an advanced stage. Preliminary reports indicated a beneficial response from the feeding of cobalt.

Pining - United Kingdom

Pining in sheep and cattle (53, pp.335-340) resembles "Bush-sickness" in New Zealand. This condition was found to be widespread in Great Britain particularly as regards to sheep. The soil (52, pp.99-100) types affected vary from blown sand, with a high proportion of shell fragments, to granite types (87, p.262) and various conglomerates. Typical symptoms of retarded growth in young animals, with anemia in some but not in all areas, was found. The condition was not as acute and general in older animals. The critical period (71, pp.274-286) was between the months of March and August and pining was noted to be more severe during wet years than dry years in some areas while the reverse was true in other areas (88, p.156). A severe parasitic problem is generally present but not in all cases. Changes to healthy pastures are curative, while affected sheep may be carried on pining farms if supplemental feeding using linseed cake and field turnips is practiced (71, p.286).

The parasitic problem (88, p.156) followed the severity of the pining cycle making a more complicated case to diagnose. It was concluded that pining in sheep was due to the combined effects of malnutrition and a gastrointestinal parasitic infestation. Where phenothiazene was used in clearing the worm picture it was found that recovery was not complete unless cobalt was used. Hemoglobin values (52, p.103-104) of 6.28 to 8.70 grams per 100 milliliters[3] for sick cattle was found while cattle in fair to good health had hemoglobin values from 7.57 to 10.75. Sick sheep presented hemoglobin values of 6.12 to 9.25 grams per 100 ml compared to 10.16 to 11.43 for healthy animals with levels varying throughout the year. Indication (87, p.262) is given that the cobalt content is related to the magnesium content of the parent rock. The soil showed no relationship (30, p.1802) between the iron, copper, manganese, and cobalt content. Soil values (96, pp.57-59) in the pining areas generally showed five ppm or less of cobalt. Responsive uptake in

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3. Milliliters will hereafter be designated as ml.

plants was obtained over a period of 15 months or longer where 80 pounds of cobalt chloride were added per acre. A two pound cobalt chloride application per acre to pastures also gave effective prevention with grazing animals.

Pasture analyses (30, p.1802) for cobalt varied with values from 0.05 to 0.20 ppm for spring to 0.05 to 0.12 for summer and did not appear to be related to the incidence of the disease. The deficiency was experienced on both high and low cobalt value forages. Pining area pastures (86, p.363) with mean cobalt values of 0.20 ppm were plagued with pining while areas with mean cobalt values of 0.45 ppm were free of pining trouble. Cobalt administration was effective in curing the pining condition. In one area (88, p.156) pining was not accompanied by general malnutrition. An untreated pasture in one affected area (78, p.726) on dry matter basis had 6.3 ppm molybdenum and 0.07 ppm cobalt. When two pounds of cobalt chloride per acre were added this caused an increased uptake of molybdenum to 9.2 ppm and a proportionate increase in cobalt content to 0.20 ppm. Eighty pounds cobalt chloride added per acre increased the molybdenum to 14.2 ppm and cobalt to 2.75 ppm, showing the possible influence of cobalt on the molybdenum level in the forage. The importance of this phenomenon will be apparent when the section on molybdenum excesses is reviewed. Decreasing soil acidity was also pointed to as a factor in causing greater amounts of molybdenum to be absorbed by the plant.

Grand Traverse or Lake Shore Disease - Michigan

The disease in Michigan (11, pp.68-70) is generally found near and around the sandy lake shores of Northern Michigan. It has been noted occasionally on heavier soils.

The symptoms are lack of appetite for feed and water, depraved appetite--chewing of wood, leather, rope, bark, stumps and bones--and emaciation with subnormal hemoglobins usually but not always present in later stages of the disease.

Roughage (65, p.281) is the principal source of cobalt and when the cobalt values drop below 0.07 ppm, the condition is usually encountered in one form or another with younger animals more susceptible than others.

Dramatic recovery is effected in three to ten days by feeding cobalt and prevention is obtained by providing a salt lick containing cobalt at the rate of one ounce per 100 pounds of salt or supplying the necessary mineral through the grain ration. As a precaution cobalt supplement is used throughout the State (38, pp.1-5).

Neck Ail - Massachusetts

General location of the trouble was in the southeastern section of Massachusetts (2, pp.59-68) near a lake region known as Buzzards Bay. This condition which affects cattle had been prevalent for years. Makeshift cures were used; these included purchase of outside feeds, shifting to "healthy" areas for growth and wintering of young stock, feeding of proprietary conditioning powders and various other expedients. Ferric ammonium citrate was used as a treatment with the belief that an iron deficiency was the cause following the same trend as experienced in early work in New Zealand. Hemoglobin values were low in advanced cases. Throughout, all work was centered in proving an iron deficiency. Archibald et al, in a footnote, state that this condition which is similar to "Bush-sickness" is due to cobalt deficiency according to the finding of Underwood and Filmer (101, pp.604-605) in Australia.

Cobalt Deficiency - Canada

No direct evidence (20, p.15) was found for a natural occuring cobalt deficiency in Canada but symptoms were experimentally produced by feeding nonleguminous forages from the Province of Alberta. Affected ewes produced small, weak lambs, had weak fibered fleeces and insufficient milk for the lambs. Other general symptoms included poor appetite, and weight loss followed by unthriftiness and death. Hemoglobin and cell volume were lower in affected animals as compared to normal animals.

Alfalfa hay and ash of this hay were beneficial (20, pp.23-24) when fed while iron and copper gave no improvement, in fact they seemed to be detrimental. Four mg of cobalt twice weekly alleviated and prevented the condition for sheep. Cobaltized salt (22, p.481) was effective as a preventative. Estimations (21, p.322) of cobalt content in the blood, liver, and spleen showed no great differences in the blood, while the liver and spleen followed a more definite pattern of reduced cobalt content in the affected animals. Non-leguminous (20, p.27) hays showed a cobalt content of 0.01 to 0.02 ppm while alfalfa grown on the same type of soil as the non-legumes had a cobalt content of 0.16 ppm. Alfalfa from a different area was found to have a cobalt content of 0.012 ppm.

Cobalt Utilization

That cobalt must be ingested to be of value (14, p.99) is supported by the fact that cobalt becomes concentrated in the microorganisms which inhabit the rumen (100, p.503-504) and if the cobalt level is not maintained, the rumen flora are markedly changed with the cellulose acting microorganisms primarily affected. Cobalt elimination (29, pp.67-68) is rapid and continuous with less than one percent of the initial dose being retained after a seven day period. The greater portion of cobalt, approximately two-thirds, is eliminated in the feces. In-so-far as is known (27, pp.155-158) the intestinal tract appears to be the chief point of absorption with the liver being one of the chief concentration points outside the intestinal tract. The kidneys (25, p.383) carry a relatively high proportion with traces taken up by all tissues. Some cobalt is found in the bile pointing to a possible route of elimination.

Pasturage or hay containing less than 0.07 ppm of cobalt seems to be inadequate for cattle. Five to 15 mg per day of cobalt is clearly adequate (58, p.739). Excesses of cobalt produce a condition known as polycythemia (62, pp.527-533) and the rate of 50 mg per day per 100 pounds live weight seems to be the maximum for calves before increases in hemoglobin packed red cell volume, polycythemia, loss of appetite, decreased water consumption, rough hair coat, lacrimation and lack of muscular co-ordination are produced. Methionine (44, pp. 328-330) administration appears to be helpful in the relief of polycythemia. Polycythemia in mature cattle has not been observed.

Vitamin B_{12} is a biproduct (76, pp.84-85) of microorganism synthesization and contains approximately four percent cobalt (67, p.491).

The results, as experienced by various workers (55, pp.703-704), of cobalt administration in arresting acetonemia (57, pp.292-304) have been varied with good results in some cases while a few failed to respond. It was felt that acetonemia might be a symptom of a larger syndrome.

Certain practices in relation to cobalt fertilization should be noted (6, pp.688-693). Where sufficient cobalt is available indications are that legumes will take up a greater quantity of cobalt than grasses but the legumes are less tolerant of cobalt and will show toxic symptoms quicker. Phosphate favors cobalt uptake while lime, under certain circumstances, has a depressing action particularly when the cobalt is mixed with the lime. Cobalt causes an increased molybdenum uptake (78, pp.725-726).

Copper Deficiency

Table II presents a brief partial summary showing the normal and abnormal copper values in the forages. The various disease

TABLE II.

Copper Deficiency Summary

Disease	Country and References	Forage Cu Analyses		Liver Cu Analyses		Corrective Measures
		Abnormal	Normal	Abnormal	Normal	
		ppm	ppm	ppm	ppm	
Enzootic Ataxia (sheep)	Australia 12,17,77	1.3-5.0	above 5	15 (sheep)	113-800 (sheep)	copper licks top dressings
Falling Disease (cattle)	Australia 12,18,92	1.1-2.2	7-12	1-6 (2.1)* (6 cows)	37-221 (122)* (6 cows)	copper licks top dressings
"Scouring" disease (cattle)	Holland 92	3.6-10.5	above 10	---	---	copper plus cobalt
"Licking disease" (cattle)	Holland, Sweden, Germany 92	2-3	6-12 (7.5)	---	---	copper drench molasses with 14-16 ppm Cu top dressings
Copper Deficiency (cattle)	New Zealand 34,35	1.8-5.5 (3.6)*	8.1-18.7 (11)*	2.9-32.0 (11.5)* (41 cows)	23-409 (200)* (23 cows)	copper licks top dressings
Normal (cattle)	Wisconsin** 51	---	---	---	165-578 (301)* (90 cows)	

* Figures in parenthesis are means of the ranges.

** This work was carried on in conjunction with investigations involving trace minerals and brucellosis and the mean has been recalculated by this author.

names and countries connected with copper deficiencies are indicated. Liver copper values are given for normal and abnormal animals. Values below 200-300 ppm might be considered as questionable, due to several factors. One is the small number of samples. Another is the possibility that these animals may have originated from border-line areas adjoining copper deficient areas. The probability of molybdenum influence also has not been excluded.

Enzootic Ataxia - Australia

This condition is dealt with primarily as it affects sheep. Other areas have experienced "peat scours" and enzootic ataxia on land where both cattle and sheep are operated in the same general locality. The contribution of Bennett and Beck (17, pp.4-18,30-32) is of such importance that it is necessary to deviate from the bovine species to obtain a general picture and background of the affected Australian area. Along the west coast of Australia extending inland some ten to twenty miles is an area where the condition is known as "Gingin rickets" after the district where the condition was first recognized. The soils affected vary from a sandy and gravelly type to those of granite origin. A high lime content is present in many of these soils. The disease occurs in unweaned lambs of ewes grazing on the affected areas. Lambs one to two months of age are most commonly affected. These become unthrifty and stiff gaited with retarded growth. When driven, the lambs become ataxic with no anorexia. The disease develops fairly rapidly and the lambs usually die in three to four weeks. Generally, if they are three to four months old, the disease is less severe and recovery is almost certain. After muscular incoordination once develops, the disease progresses very rapidly and death generally occurs in three to four days. The condition does not appear to be seasonal but lambs born in the late spring and dry summer seem to be less affected than those born earlier. Lesions (77, p.24) in the brain and spinal cord appear in severe cases while hemosiderosis of the liver, spleen and pancreas is found in many instances. Anemia was not found to be a constant feature of the disease although it was observed in some cases. Anemia is likely to be present in the ewe, particularly if the acute form of ataxia is present in the lamb. Diarrhea, loss of condition and stringy wool are characteristic symptoms noted in the ewes. It was found that copper given to ataxic lambs arrested the disease while copper fed to pregnant ewes prevented the disease in the lambs.

Composition of the organs showed liver copper values for both ewes and lambs below 15 ppm while healthy animals had values between 150 and 350 ppm for lambs and 113 and 800 ppm for ewes.

In the milk of affected ewes a similar picture of low copper values was present with 0.03 to 0.05 mg per liter against 0.12 and 0.19 for healthy animals. In the milk of healthy ewes, there was a decline in copper from 0.20 to 0.64 mg per liter to 0.04 to 0.16 mg per liter several months later.

Soil analyses (97, pp.164,171) disclose a copper content of one to two ppm on a dry matter basis while oat and hay samples grown on this soil had a value of 1.1 to 3.9 ppm. It was noted that different pasture (12, pp.285,290,293) species vary in their assimilative ability while variations were also present due to stage of maturity. Short pasture in the early growing period had a copper content of 3.1 ppm while the value dropped to 1.3 ppm at the mature dry stage. It was proposed that the reason sheep graze selectively by taking the leaves and leaving the stems was due to the higher copper content of the former.

Classification of sound, marginal, and unsound pastures had respective copper values of 5 ppm or over, 3 to 5 ppm, and less than 3 ppm.

During years favoring better pasture growth with increased rainfall and dull days a greater occurrence of the disease was noted compared to drier years. A hypothesis was presented that the copper in green forage during wet years was not as available to the animal as in drier years.

A 20 pound per acre application of copper sulfate on faintly acid soils increased the copper level in the herbage from 2.5 ppm to 14.8 ppm on a dry matter basis and this persisted for three years with moderate decline. By marked contrast on calcareous soils only a slight increase was made in copper level when 100 pounds of copper sulfate was applied per acre.

"Sudden Death" or "Falling Disease" - Australia

The area of this condition is located in southwestern Australia (92, p.46) and was first brought to the attention of the Australian

Agricultural Department in 1929. It was classed as an enzootic disease of dairy cattle characterized by sudden death. The soil types varied from heavy loam to gravelly soils and gray sand soils.

The flush growing period produces the greater number of cases (18, pp.85-92). Even though there is abundant growth the cattle will show some loss of condition, a rough, staring coat, evidence of anemia, and depraved appetite. Diarrhea, although sometimes present, is not characteristic of the disease. The incidence varies from year to year. Limb abnormalities are present in young calves along with stunted growth and the cows show suppressed oestrus and temporary sterility. Five to forty percent of a herd may die. Cattle only are affected and ataxia has been determined pathologically on post mortem while calves and foals show a rachitic-like condition similar to that experienced in West Australia. Dead animals present a congestion in the abomasum and small intestine, a very friable liver, and dark pulpy spleen. The blood picture was concluded to be an anemia which is of the macrocytic, hypochromic type with hemoglobin averages for healthy cows averaging 13.3 grams percent and anemic 6.7 grams percent. One hundred mg copper sulfate daily, administered orally, corrected the condition and maintained a good hemoglobin value throughout the year.

Liver copper values for cows which died of falling disease had a mean of 2.1 ppm dry matter while other cows, yearlings, and calves in the deficiency area had a mean value of 5.7 ppm. Healthy cows in sound areas had a mean of 122 ppm dry matter basis. Milk copper values were 0.01 to 0.02 mg per liter for affected areas against 0.05 to 0.20 mg for normal areas (13, p.150).

Pasture composition (92, p.49) is worthy of note as many of the grasses named are found in the Oregon coastal area. Subterranean clover did well initially, with some persisting. It has been replaced largely by dropping flowered clover (T. cernum), as the predominant legume throughout the area. Grasses come into prominence later in the year and deaths become more infrequent or cease with a predominance of grasses which include: Yorkshire fog (velvetgrass), sweet vernal, silver weed, spear grass, ryegrass, and barley grass. The subterranean clover experience has been true in areas of Clatsop County, while the other named grasses are common in the Oregon coastal area with the exception of barley grass and spear grass.

Copper values (12, p.285) in the pasture showed 1.1 ppm to 2.2 ppm, generally 5 ppm or less, for affected areas, against 7 to 12 ppm in adjacent healthy areas.

"Wobbles" in Foals and Calves - Australia and U.S.A.

This condition occurs in foals and calves in areas of Australia where enzootic ataxia and "falling disease" is found (16, p.305). A similar sporadic condition was reported in the United States where it occurs on limestone soils (85, pp.306,313).

In lambs the condition is designated as ataxia which is a nervous disorder manifested by a characteristic incoordination of gait. The condition in foals (calves) is said to simulate true rickets.

The foals are unthrifty with a depressed growth rate followed in advanced cases by stiffness and enlarged joints. Animals frequently stand on their toes as a result of contracting tendons. This may be apparent at birth or develop within six months. The stiff joints and toe standing disappear after weaning and the animal grows slowly even though concentrates and good pasture are available. Involvement (17, p.12) of the central nervous system does not appear to be a factor in Australia but characteristic lesions of ataxic lambs were found in foals in the United States (85, pp.303-304).

Evidence presented indicates copper is at fault and corrections were obtained when proper therapy was administered.

"Scouring Disease" - Holland

This disease affecting cattle (92, pp.51-54) and goats was noted on freely drained sandy soils and the sandy soils of the reclaimed Zuider Zee area in Holland.

Cattle develop a severe diarrhea, loss of weight, and depigmentation of the hair. Diarrhea was a more dominant symptom in Holland while the "Bush-sickness" in Australia and pining areas to be discussed later showed little scouring, and then, generally, at the terminal stages. Affected animals lose their appetite, consume water frequently and milk production decreases. A below normal hemoglobin value was found in some cases. The disease occurs most often during pasture time and may commence after varying periods on pasture. Rainy seasons seemed to cause more severe attacks.

Copper was effective in controlling the disease with better results being obtained when copper and cobalt were fed together. Blood values were low in copper content while the liver and spleens were low compared to normal animals. There also was found an excessive iron content in the organs mentioned. Hair copper values of affected animals were 1.8 to 3.4 ppm compared to 6.6 and 10.4 for healthy animals.

Pasture analysis in the affected areas showed copper values of 3.7 ppm to 10.5 ppm dry matter basis, while hay contained 3.6 to 4.65 ppm. One sample of affected grass had a copper value of 7.3 ppm dry matter compared with values of not less than 10 ppm for normal grass. Manganese values were found to be low in the affected areas also. Manganese contents of 43, 30 and 28 ppm were found as compared to 170 ppm for normal healthy pastures. However, this condition has not always been noted in copper deficient areas.

"Licking Disease" - Europe

In Holland, Sweden, and Germany, a condition (92, pp.54-56) is found which is characterized by certain symptoms. These include decrease in appetite, with ensuing emaciation, dry coat, enlarged head, hard feces, frequently covered by mucus. There is a tendency of general pica with occasional anemia. These abnormalities were caused by an inadequate copper level. The condition seemed to predominate on sandy and moor soils with the reclaimed lands from the sea placed in this category.

Young animals show a retarded development, mature animals show abnormal sexual activity and a decrease in milk yield. Young heifers are more severely affected but cattle of all ages are not immune. Chronic diarrhea is a factor in later stages and animals finally die of general ill health. The condition is present throughout the year and seems to be aggravated on moorland in wet weather. The disease may be controlled by feeding suitable concentrates or transferring the animals to healthy pastures.

Feeding experiments using copper sulfate as a supplement gave a complete cure relieving all the symptoms previously described and raising the hemoglobin values. Two forms of the disease were suspected, one which caused a lowered hemoglobin value and another which did not produce anemia. Iron content of the blood seemed to be somewhat lower in heifers, being approximately 10 to 15 mg per 100 ml lower for affected animals. Other ingredients of the blood such as sugar, acetone, urea, calcium, phosphorus, magnesium, sodium, and chlorine seemed to be normal.

Copper values for hay were two to three ppm for unhealthy areas, against an average of 7.5 ppm dry matter for healthy areas. Curative pasture showed a copper content of 15 to 30 ppm. Copper sulfate application to the soil was an effective cure as was a similar practice for correcting "reclamation disease" in plants which occurred in "liksucht" areas. In Sweden this condition is cured by feeding molasses containing 14 to 16 ppm copper. In Germany the Schleswig-Holstein and Schwarzwald area have experienced trouble similar to that described for Holland.

Dual Deficiency of Cobalt and Copper

Coast Disease - Australia

The main areas (77, pp.28-29) included under this disease are three islands off the southwest coast of Australia and the adjoining area on the mainland with other isolated areas under suspicion. Type of soil affected is generally on calcareous coastal dunes composed of windblown shell fragments.

Marston et al (77, pp.14-21) point to the similarity of coast disease, enzootic marasmus, bush-sickness, pining, and Nakuruitis which have been previously covered. Disease symptoms include loss of appetite, lethargy, weakness, emaciation and blanching of the visible mucous membranes. Anemia progresses as emaciation becomes more severe. In sheep the symptoms of coast disease are often visible before anemia develops. Hemoglobin values fall as the disease progresses and this change is accompanied by a decreased blood volume with consequent reduced heart efficiency. Autopsy reveals general malnutrition, edema, atrophy of the viscera, light and fragile bones and hemosiderosis of the liver, spleen, and pancreas. In acute areas young cattle (92, pp.30-33), adult wethers, dry ewes, weaners, pregnant and lactating ewes develop the disease in a few months. Removal of animals to unaffected areas brings about rapid improvement and recovery depending upon the stage of development of the disease in the animals. Sheep in some areas show no significant parasitic infestations.

Feeding experiments showed that supplemental carbohydrates, portein, and phosphorus did not prevent the disease. Copper alone was ineffective. When cobalt was administered daily to the animals receiving copper, an improved appetite and condition were noted. Cobalt alone was not too effective. Iron and copper failed to prevent terminal phases from developing.

Composition of sheep blood showed very low hemoglobin values in the final stages of the disease. Reduction in the number of red cells seems to be the main cause of the degree of anemia. Abnormally high concentrations of iron were found in the liver, with the spleen and kidneys showing some trend to higher concentration. Treatment with copper and cobalt showed a reduced iron concentration while the copper values were not materially affected. The existence of copper deficiency is substantiated by the simultaneous appearance of ataxia in lambs and "steely" wool in sheep.

Soils in the coastal area showed a high calcium, iron and phosphorus content with the following trace element values: cobalt 0.0 to 3.9 ppm, nickel 0.0 to 39.2 ppm, and copper 2.6 to 17.1 ppm.

Pasture values showed low cobalt and copper contents which could be corrected by top dressings.

"Salt Sick" - Florida

This condition in Florida was first described as early as 1888 (15, pp.5-11). The soil consists of white and gray sands, muck lands, residual soils overlying moor, and peat soils. The disease occurs mainly in cattle, but sheep, goats, and swine are also affected. Animals exhibit almost complete loss of appetite, emaciation, weakness, and pale mucous membranes. Some animals refuse all feed offered and eat dry weeds and other material which are refused by healthy animals. Diarrhea is present sometimes while other cattle will have feces which are dry and hard resembling those of sheep. Animals in good flesh often lose condition rapidly. Growth is retarded. Some two year olds will attain only half their normal weight. Sexual maturity is delayed in many instances. Parasites may be a factor but are not always associated with the condition as animals which were free of parasites developed the syndrome. Blood is pale in color with as little as one-fourth the normal red pigmentation. Blood volume is reduced. The pulpy portion of the spleen is atrophied with the liver and kidneys somewhat pale in color. The heart muscle is flabby and lacks tone.

Cattle six months and older are more frequently affected, with heifers, after dropping their first calf, frequently being more susceptible. Greater mortality is noted among young cattle. The condition does not appear to be seasonal. Dairy cattle receiving four pounds or more of mixed concentrates are seldom affected.

In early times the condition was alleviated by transferring cattle from affected to non-affected ranges until the cattle had recovered, after which they could again be shifted back to the salt-sick areas for another period of six to ten months. As ranges came under fence cattle could not be shifted from sick to healthy areas and it was necessary to supply the missing nutrients. In some areas copper and iron oxide were ineffective as a cure. It was found that cobalt administration (80, p.226) was necessary for normal growth and function. The most striking thing about cobalt (81, pp. 744-751) was its effect on the return of appetite. In general, the hemoglobin values were lower for affected animals, although a few were quite high. It was concluded that hemoglobin values may be affected by both blood volume and other physiological functions, and that after allowing for normal variations, cannot be regarded as an exact measure of changes in total hemoglobin.

Neal and Becker (82, pp.561-562) found that the average hemoglobin value for 87 animals visibly affected was 8.28 grams per 100 ml and after one month's treatment with an iron-copper supplement, this was raised to 10.61 grams per 100 ml. A subsequent check on 79 of the original group when nearing complete recovery showed a value of 11.55. Healthy cattle from the same herds averaged 13.86 grams per 100 ml of blood. Neal and Ahmann (81, pp.748-749) found that some calves gave an apparent increase in hemoglobin values when they lost condition, with no level so low as to be classed anemic. Animals receiving cobalt generally had a higher concentration of hemoglobin per cell and the per cell volume was higher. The individual cell was larger in cobalt-treated calves. Animals not receiving cobalt showed an increased proportion of leucocytes to erythrocytes.

Hemosiderosis (81, p.749) of the liver and spleen was observed in affected calves. Excluding the bones (89, p.50), the tissues of salt sick calves were higher in copper values than normal calves. Examination (90, pp.31,39) revealed no significant differences for cobalt.

Rusoff and co-workers (91, p.733) found no spectographic difference for copper values in wire grasses between healthy and salt sick areas; values were 4.7 to 10.1 ppm.

Copper in Animal Tissues and Secretions

A relatively (76, pp.90-91) high concentration of copper in the liver provides the main reserve supply which is utilized when the intake of copper is insufficient to make good that which is lost in secretions and excreta. The liver copper value (26, pp.910,912) for the newborn bovine offspring is four to eight times that of the maternal liver. This ratio persists for approximately one and one-half months. Copper values for various tissues with high values declined in the following order: liver, kidney, gastrointestinal tract, adrenals, thymus, gall bladder, and bile. Copper present in these organs indicates the mode of excretion which is primarily by the way of the feces with only a negligible amount excreted in the urine.

The following organs (24, pp.202-208) had a medium concentration: pancreas, red bone marrow, intestinal lymph, blood, spleen, heart, lung, and reproductive organs. Low concentrations were present in the white bone marrow, muscle, hide, bladder, ligament, cartilage, bone, eye, and nerve tissues. Soluble copper absorption appears to be rather slow as demonstrated by radioactive tracer. Five days after oral dosage 75 percent of the original dosage was excreted in the feces and approximately three percent in the urine.

In a similar period copper injected intravenously was excreted about equally in the urine and feces with only six percent of the original injection being excreted in five days. The comparative excretory elimination values were determined by using radioactive copper administered orally as compared to jugular injection. Determinations were made after the animals were sacrificed.

Oral copper administration had 29.1 percent of the original dose in the large intestine against 0.6 percent for the injection method. The liver contained 1.0 percent under oral administration and 32.6 percent with the injection administration. The orally treated animal was slaughtered 46 hours after treatment while the injected animal was sacrificed 19 hours after injection.

The following copper proteins are present in animals (37, pp. 230-233): hepatocuprein found in ox liver contains 0.34 percent copper; hemocuprein found in the blood of ox, sheep, and horse contains 0.34 percent of copper; while copper protein is present in cow's milk with a copper content of 0.19 percent. When 289 mg of labeled copper was fed to a dairy cow only 0.005 percent of the dose was found in the milk (24, p.205).

Conclusive evidence that copper functions in the utilization of iron has been known for approximately twenty years (46, pp.309-319). This has been demonstrated by feeding iron to copper depleted rats and noting the build-up of the iron content in the liver and spleen. The condition of excessive iron build-up in the liver and spleen is known as hemosiderosis and appears in animals with a copper deficiency. When copper was supplied it caused the iron to be transferred to the hemoglobin with a small increase in the size of the spleen, and a small decrease in iron content of the spleen. Another relationship (93, pp.357-371) of copper and iron causes an increase in reticulocyte levels which increase from 1,500,000 to 1,700,000 per cubic millimeter in four or five days when copper and iron are withheld from border-line deficient rats. Copper is indispensable for the transformation of absorbed iron into blood and has no direct effect upon formation of the erythrocytes of blood except its influence on hemoglobin formation. Evidence is available (23, pp.97-106) which shows the cytochrome and cytochrome oxidase content is influenced by the presence or absence of sufficient quantities of copper and iron. Iron alone did not produce the same effect as when copper was included. The A component of cytochrome was more rapidly affected than cytochrome B and C. The latter two were affected over a longer period of time. Cytochrome is one of the components necessary for the manufacture of blood. Cytochrome oxidase and catalase are both iron-containing compounds (76, p.94).

Evidence continues to accumulate to substantiate the importance of pantothenic acid and copper in the pigmentation process of the hair coat. When a pantothenic acid (60, p.385) deficiency is produced in rats the copper in the skins of rats increases approximately fivefold above that of normal. When either pantothenic acid or copper is supplied (95, pp.472-473) the impaired pigmentation process is restored. This point raises the question (76, p.94) as to whether pantothenic acid is involved in the linkage of copper to the protein combination of the polyphenoloxidases.

The physical nature of the hair in copper deficient animals, including pigmentation in many instances, has practically always been commented on by all authors describing copper deficiency symptoms.

Copper was found (54, p.185) to be the only active agent when many vitamins and minerals were fed to control depigmentation in young rats, cats and rabbits. The minerals used included: copper, iron, manganese, zinc, cobalt, nickel, sodium, potassium, calcium, magnesium, fluorine, chlorine, iodine, phosphorus and sulfur. All these were tested separately and together and copper was the only element which prevented or cured the condition.

A phenomenon described by Marston (75, pp.233-237) is the role of copper in the keratinization of wool. One of the first visible symptoms in uncomplicated copper deficient sheep is the breakdown in the keratinization process which causes a lesion in the wool particularly in the Merino breed. The close even crimp imparted to normal wool becomes progressively less distinct until the fibers emerge from the follicles as a wavy, characterless, hair-like growth, devoid of crimp. Essentially, the breakdown is due to insufficient copper which is necessary for oxidation to take place in the wool formation within the follicle. When copper is administered, the oxidation process is renewed within a few hours.

The importance of copper as an oxidizing agent in the animal body may be linked to similar functions found in plants as certain plant enzymes are known (3, pp.99-108) which contain copper. Briefly these include laccase which acts on P-phenylenediamine and will oxidize ascorbic acid directly in plants. Ascorbic acid oxidase in plants functions as an oxidizing agent for ascorbic acid under certain conditions. Polyphenoloxidase (tyrosinase), a copper enzyme, catalyzes the aerobic oxidation of a variety of phenols.

Toxicity of Copper

The effects of chronic copper poisoning have occasionally been noted in husbandry practice and have been encountered mostly through negligence. This has come about by the use of copper-containing fungicidal sprays in horticulture and then allowing animals to graze contaminated forage. Other copper poisoning cases have occured through improper handling of copper supplements (76, pp.92-93) in copper deficient areas and improper use of certain emetics for control of parasites. When excessive copper is ingested the copper concentration in the liver increases more or less rapidly to very high levels, without external symptoms in many instances, until excess copper is liberated in the blood stream. At this stage hemolysis takes place, the animal becomes jaundiced and death usually occurs. Examination discloses congested, gun-metal colored kidneys and the blocking of the uriniferous tubules with hemoglobin derivatives is apparent.

When a daily dose of five grams of copper sulfate was fed (63, pp.623-624) to a 500 pound steer, death occurred in 122 days. On the 102 day of the trial inappetance and diarrhea took place. The kidneys were found to be enlarged with a black marbled surface. The spleen was enlarged and soft and had a dark color. The liver disclosed a yellowish appearance with a hard surface and a dirty yellowish colored fat was found to be present in the membranes. Hemolysis and hemoglobinuria was present in the animal.

Cunningham reports (33, p.372) that five grams of copper sulfate were fed daily for nine months to a 710 pound animal without harm. A normal calf was produced after this period of copper feeding. Repeated doses of 20 to 40 grams of copper sulfate were tolerated by cattle and 200 to 400 grams of copper sulfate were fatal in single doses.

Copper and Molybdenum

A brief copper-molybdenum summary is shown in Table III. The copper values in most instances would be considered adequate without excess quantities of molybdenum. The variable quantities of molybdenum caused the liver copper values to decline, resulting in abnormal values.

TABLE III.

Copper-Molybdenum Summary

Disease	Country and References	Cu Forage Analyses	Mo Forage Analyses		Liver Cu Analyses		Corrective Measures
			Abnormal	Normal	Abnormal	Normal	
		ppm	ppm	ppm	ppm	ppm	
"Teart" pasture (cattle)	Somersett, United Kingdom 47,48,68,69	11-18	20-100	5	---	---	1-2 gm copper sulfate fed daily
"Non-teart" pasture (cattle)	Cheshire, Shropshire, United Kingdom 1	8.2-22.7 (14.2)*	2.3-7.4 (4.4)*	0.6-1.8	5.7 (1 cow)	---	1-2 gm copper sulfate fed daily
Pining (calves)	Caithness** United Kingdom 61	4.8-20.8 (11.2)*	3.8-19.5 (6.5)* 1.1- 4.3	---	0-160 (22.1)* (56 cows)	20-220 (86.1)* (31 cows)	daily feeding copper sulfate
"Peat" scours (cattle)	New Zealand 34,35	8.1-18.7	2.5-11	0.5-3.5	9 (? cows)	23-409 (200)* (23 cows)	drench top dressings licks
Normal (cattle)	Wisconsin*** 51	---	---	---	---	165-578 (301)* (90 cows)	Normal cows

* Figures in parenthesis are means of the ranges.

** The liver copper means are approximate. These were recalculated by this author from the data available.

*** This work was carried on in conjunction with investigations involving trace minerals and brucellosis.
The Cu mean shown has been recalculated by this author.

"Teart" Pastures - United Kingdom

In 1910 it was estimated that some 20,000 acres were affected in the Somerset area (47, p.44) by a condition which caused scouring in cattle. Similar land occurs in Warwick (68, p.52) and Gloucester. The condition has been known to exist for over 100 years and is commonly classed as "teart pastures" and these may cause "scouring disease".

Milk cows and young cattle (47, pp.44-50) are primarily affected with sheep also being susceptible. Symptoms may start in May or June but the worst period is during August, September, and October with mild damp seasons causing more trouble than drier periods. Scouring is one of the most notable characteristics and generally starts after the animals have been grazed for eight or ten days. Animals lose weight, develop poor coat condition with depigmentation, and a general decline in condition takes place. Milk yield is affected and there was a belief among some farmers that animals would be permanently injured if left on "teart" pastures too long. Highly "teart" pastures in time cause dairy animals to have tender swollen leg joints and the udders often become swollen and lumpy. Parasites do not appear to be a factor. The condition may be corrected by moving cattle to healthy pastures. Ferguson et al (47, p.47) by trial feeding of molybdenum salts produced scouring in most instances using cattle from "teart" areas while cattle from non-"teart" areas either did not develop the symptoms or it was necessary to use larger dosages. Three possible conclusions were reached as to the molybdenum action: the effect was due to the molybdenum being absorbed in the bloodstream; the molybdenum may prevent some element from producing its effect which is essential for health; or molybdenum may cause a catalytic action which would produce certain toxins.

Extensive field trials (48, p.118)(47, pp.50-51) giving two grams of copper sulfate to mature cattle and one gram copper sulfate to young cattle daily prevented scouring on very "teart" land while smaller doses were satisfactory for mildly "teart" land.

Soils, in the affected areas, according to Lewis (68, p.56) are calcareous and alkaline with large amounts of molybdenum present. Acid soils did not appear to be "teart" while calcareous soils with a neutral to alkaline pH were "teart".

Ferguson (47, p.46) made pasture analysis and found the only peculiarity was the high molybdenum content, 20 to 100 ppm on a dry matter basis for "teart" areas compared to 5 ppm for non-"teart" areas. It was found (69, pp.58-63) that clover had 95 ppm compared to 50 ppm for grasses in the "teart" areas. Yorkshire fog (velvet grass) was unusually high in molybdenum content but this forage was seldom an important factor in the pasture species. Copper content of the "teart" and non-"teart" forages varied from 11 ppm to 18 ppm dry matter basis. One very "teart" area over a three year period showed a molybdenum content ranging from 32 to 49 ppm for April, 66 to 83 ppm in September, and fell to 29 ppm in December. Samples showed (47, p.47) that 70 to 80 percent of the molybdenum in green pasture was water soluble, about 40 percent in hay was water soluble, and ten percent was water soluble in dead winter herbage. It was suggested that the pH of the soil may govern the uptake of the molybdenum in the plant. Sulfate of ammonia fertilizer reduced (69, pp. 59,63) the uptake of molybdenum by one-half to two-thirds throughout the entire growing season. This practice produced a beneficial herbage increase. "Teart" pastures could be produced by adding sodium molybdate and the pasture had 190 ppm dry matter in May after 20 pounds were added in January.

Non-"Teart" Pasture - United Kingdom

A condition (1, pp.205-217) was found on peat type soils in the area of Shropshire and Cheshire which are similar to the peat scours areas of New Zealand (34, pp.381-395)(35, pp.246-273). Scouring differed in this area, however, in that the scouring continued through the summer with less scouring in the winter. A general condition of low production and stunted animals was characteristic. Pastures were found to have copper values from 8.7 to 22.7 ppm, with a mean of 14.2 ppm dry matter basis. Molybdenum values ranged from 2.3 to 7.4 ppm with a mean of 4.4 ppm. Only a slight difference was noted in hemoglobin values, between controls and treated animals receiving copper sulfate, with values ranging from 7.6 to 12.6 grams per 100 ml. The mean was 9.7 grams per 100 ml.

Blood copper values were low for adult animals. They were 0.02 to 0.04 mg per 100 ml with a mean of 0.028 mg per 100 ml before treatment followed by levels of 0.07 to 0.09 mg per 100 ml attained after treatment with copper sulfate.

Another condition described as copper pine in calves in Caithness (61, pp.16-31) effects grazing calves of Aberdeen-Angus and crossbred West Highland breeds chiefly. Adult cattle apparently are not affected. This condition is found on peat soils with underlying sandstone formation.

Symptoms appear about one month after being on pasture with "stilted" gait particularly in the hindquarters. There is a slow loss of condition during the four to five month pasture period. Severe cases generally terminate in death. Black-colored animals show gray around the eyes giving a "spectacled" appearance frequently extending to the forehead and jaw. In severe cases graying is found over the body, but most cases are limited to graying along the back and forelegs. Brown colored animals will often turn a muddy yellow. Diarrhea is not common but has been observed in instances.

From 25 to 100 percent of the calves are affected with variation from year to year. Animals suffer throughout their lives by showing sub-optimal growth. Liver copper values for calves were low, 4.2 to 7.7 ppm. Two-thirds of 45 random liver samples obtained from slaughter houses had less than 20 ppm of copper, on a dry matter basis, in the affected area while livers from another area showed one-fourth of 42 samples below 20 ppm and investigation of these samples found pining conditions similar to that of Caithness.

Pastures showed copper values of 4.8 to 20.8 ppm with a mean of 11.2 ppm. Molybdenum values were 3.8 ppm to 19.5 ppm with a mean of 6.5 ppm. Two samples, one of 16.1 ppm, the other of 19.5 ppm, were much higher than any of the other samples in molybdenum content. The other values were 9.8 ppm or below for molybdenum. Adjusting the molybdenum values by leaving out the two high values of 16.1 and 19.5 ppm gave a mean molybdenum value of 5.0 ppm.

Copper and Molybdenum - New Zealand

Peat and wet lands (34, pp.381-395) affected embody a potential area of some 400,000 acres on both the North and South Islands. The present cleared area is 250,000 acres. Simple copper deficiency in adult cattle (35, pp.246-273) is described as a condition which causes anemia, poor development, reduced reproductive capacity, and a change in the coat color of red animals, in some instances, to a bleached yellowish color. Calves grow slower than normally and their bones will often fracture easily. Under complicated[4] copper deficiency symptoms calves are difficult or impossible to raise due to unthriftiness, spring scouring, low resistance to internal parasites, and again danger of fracture from poor bone formation. Adult cattle are often anemic, have rough staring coats and black animals will often be tinged with dull red (muddy brown) or graying in the

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4. Complicated copper deficiency is considered to be the effect of molybdenum on copper.

black areas of the coat. Animals scour heavily in the spring and less in the fall when on flush pastures which have quick tender growth. Scouring will frequently clear up without treatment when the feed "hardens". Also, scouring may be terminated if rough feed is provided or the animals are removed to areas of different soil formation. Symptoms will return, however, when the cattle are allowed to revert to the original conditions.

Cattle from healthy country generally will not be affected until they have been on the pastures for a year. There are areas where acute scouring is not present but the condition is manifested by unthrifty cattle with poor condition which develops slowly accompanied by low production.

Milk and fat production decline with severe scouring and the production will generally be affected for the whole season. Average butterfat production in two herds was increased by five pounds per acre applications of copper sulfate. One herd had an average increase of 36 pounds of butterfat per cow in a 63 cow herd while a 25 pound increase per cow was made in a second herd of 73 cows. Jerseys are reportedly more susceptible than Shorthorns or Friesians.

Beef animals and yearlings, reared in low simple copper deficient areas where the pasture is predominantly velvet grass and lotus major, exhibit no prominent scouring. However, they become unthrifty and steer size is below the breed average. Black animals will often exhibit a muddy brown coat condition. Breeding difficulties are experienced and calves are sometimes dead at birth or die soon after with slow development on survival. Cattle lose condition upon scouring but do well and fatten without trouble during the summer and autumn.

Normal pastures have an average copper value of 11 ppm with a range from 8.1 to 18.7 ppm dry matter basis. Simple copper deficient pastures show the following mean values in ppm dry matter: 3.6 (1.8-5.5)[5], 5.9 (1.7-10.6)[5], 6.9 (3.4-10.8)[5], 7.1 (2.1-10.8)[5], 7.2 (4.6-10.2)[5], 7.4 (4.7-11.3)[5]. Peat scour pastures showed a molybdenum content from 2.5 ppm to 11 ppm where peat scours were found. Pasture which did not cause scouring had molybdenum contents from 0.5 ppm to 3.5 ppm.

Liver copper values of adult cows on normal pastures had a mean of 200 ppm with a range of 23 ppm to 409 ppm dry matter basis. Deficient areas had liver values from adult cows with a mean of 11.5 ppm and a range of 2.9 ppm to 32.0 ppm (35, p.253). New born calf liver value comparisons showed values of 380 ppm on normal pastures against 55 ppm on complicated deficiency pastures.

"Redwater" Disease

This condition known as bovine hematuria (92, p.82) is of a noninfectious nature found in Australia (31, p.27)(32, p.82), British Columbia, New Zealand (74, p.101-102), and Italy. The condition (92, p.82) does not appear to be related to any particular soil type

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5. The limits of range from which the mean was derived.

and no significant differences were found in the content of calcium, potassium, magnesium, manganese, sodium, aluminum, iron, cobalt, or selenium of soils in affected and non-affected areas. A significantly higher molybdenum (32, p.28) content was found in the herbage of one affected area. Organs of affected animals (39, p.70) were low in copper and above normal for molybdenum. Gypsum (32, p.28) was found to control the molybdenum uptake in the affected areas and had a beneficial effect in controlling the disease.

Molybdenum Absorption and Excretion

Molybdenum (28, pp.915-917) is absorbed from the intestinal tract and excreted mainly in the urine, with a small percent carried out via the bile. A single dose will maintain a high level of molybdenum in the body for several days (76, p.100). If copper sulfate and molybdenum are administered together, less molybdenum is excreted in the urine. Whether the course of excretion is altered to the bile route or decreased absorption is obtained is not known (76, p.100).

Distribution studies (83, p.439)(28, pp.921-922) indicate molybdenum tends to accumulate in the liver, kidneys, and particularly in the skeleton. Studies (28, p.922) using radioisotopes indicate that molybdenum under certain circumstances tends to cause an increased absorption and excretion of phosphorus while the accumulation of copper (28, p.920) in the liver is decreased. Phosphorus is preferentially excreted in the feces when molybdate is fed, rather than via the normal urine path (94, p.558), while phosphorus storage in the bones appears to be impaired on high molybdenum.

Bone brittleness (35, pp.261-262) in heifers has been noted at times under certain conditions of high molybdenum intake and copper deficiency. Bones affected by high molybdenum intake showed a mild condition of osteoporosis and were practically normal in appearance. No microscopic defect could be detected which would account for the condition. Blood levels of calcium and phosphorus were found to be normal. Lambs on simple copper deficient pastures often experience a high incidence of fractures with definite osteoporosis symptoms. When adult cattle and sheep on copper deficient pastures are given massive doses of molybdenum they will not show a bone weakness. The effect is manifested by the development of an acute lameness. Other visible lesions are often not apparent under this condition.

The effect of molybdenum on the developing fetus and suckling calves and sheep is enhanced under certain conditions. Molybdenum (35, pp.264-265) is transferred through the placental membranes and the presence of molybdenum in sufficient quantities will reduce the placenta transfer of copper to the developing fetus. Also, molybdenum is secreted in the milk (24, p.209) as one source of elimination from the milking female.

Excessive Molybdenum Intake by Cattle

The symptoms such as scouring and change of coat color have previously been brought out (47, pp.44-47) and the immediate cause is not clearly understood. Attempts to artificially produce the condition by molybdenum administration have not always been successful. When it is attempted to reproduce this condition artificially, almost twice or three times the molybdenum is required compared to the quantity absorbed by cattle on "teart" pastures. Cattle from unaffected areas usually needed larger doses of molybdenum than those from affected areas in order to reproduce the condition when molybdenum was fed.

The immediate effect (98, pp.929-933) on two bull calves, 190 and 217 days of age, when fed 2.6 grams of sodium molybdate daily for 129 days are worthy of note. The pre-molybdenum daily gain rate approximated three pounds per day. This dropped to less than one pound per day after 90 days of molybdate feeding. Bone involvement indicated by stiffness and apparent pain in walking was noted the second week after feeding started. After six weeks' feeding the hair started to turn from black to gray. This condition was first apparent near the ears and gradually moved to all black areas of the body. The most marked symptom was lack of libido when the bulls were allowed to run with cows or heifers. On sacrifice it was found the spermatogenic and interstitial tissues were destroyed or damaged.

The question was raised as to what would be the effect on the reproductive capacity of the cow if molybdenum intake was excessive?

Autopsy showed marked cartilaginous erosions in the metatarsal joints of both calves. One metacarpal joint was affected while one animal showed a solid union of the articulating surfaces to the point of ankylosis and fusion. All leg joints showed a greater degree of erosion and irregular surfaces than in normal animals of the same age. No other rachitic symptoms except stiffness appeared in the two calves. Lymph nodes in certain areas were affected as shown by abnormal enlargement.

Molybdenum Influence on Copper Metabolism

The close resemblance of simple copper deficient animals as compared to cattle on "teart" pastures implies that the syndrome of "teart" is a manifestation of copper deficiency from another cause (35, p.266).

It has been shown that copper reserves in the liver of sheep and cattle (39, pp.70-71) may be depleted by dosing animals with molybdate and by so doing complicate the copper metabolism.

Under certain conditions where copper forage values seem to be adequate molybdate may be fed over long periods and cause a material reduction in liver copper values without producing visible symptoms of copper deficiency (35, p.259)(75, pp.239-242). Conversely, when sheep were treated with supplemental molybdenum on uncomplicated copper deficient areas it resulted in a decreased rate of copper depletion from the liver, the maintenance of a higher concentration of copper in the blood, and the development of the symptoms of copper deficiency in a severe form more rapidly (75, pp.241-243). The appearance of this condition where copper liver depletion is arrested by molybdenum, causing a concentration of copper in the tissues usually sufficient to maintain normal functions, has caused the current hypotheses to be made. This is: that molybdenum tends to fix copper in a form which is not utilizable by the tissues or interferes with the copper-enzymes in some manner.

Diagnosing Border-line Deficiencies

It is often quite difficult to diagnose border-line deficiencies as similar symptoms may be from many causes leading to confusion and uncertainty. All other alternatives for suspected deficiencies should be thoroughly investigated and eliminated.

Cobalt deficiency symptoms (76, pp.67-69) may vary widely in degree. Factors responsible are the type of soil, nature of the pastures and season of the year. Intensity of the symptoms may be quite erratic. These may vary from an acute and fatal stage, through a subacute stage, to a milder form which only affects young animals. A transient condition is sometimes encountered where no deficiency symptoms will be apparent for some years and with a change of season symptoms will appear in a subacute or acute form. In a milder form with no specific symptoms the condition may be attributed to causes other than a shortage of cobalt. A border-line cobalt deficiency in the subacute form under some circumstances will only retard the growth rate of young animals and the adult will lose weight without revealing obvious specific symptoms. Other conditions are found where calves born of cobalt deficient cows are weak and puny and the percentage of survival is nil.

Marston (76, p.69) states the following:

> The dramatic response to dosing with cobalt is the only secure diagnostic means of proving a state of cobalt deficiency. Provision of cobalt per os at any stage will arrest the syndrome, and, on the resumption of a normal cobalt status within the alimentary canal, the animals rapidly recover their appetite, increase in weight and regain their normal health and vigor.
>
> The general symptoms of cobalt deficiency are an expression of a metabolic defect which is the precursor and not the result of the anemia: they can be quite marked before any sign of anemia appears and, on appropriate treatment, they disappear before the oxygen-carrying capacity of the blood improves.

With a border-line copper deficiency (36, pp.8-9), certain changes in diet may precipitate a copper deficiency. For example, a diet adequate without molybdenum becomes inadequate or border-line in the presence of molybdenum. Alfalfa hay values may vary in molybdenum content, from 0.0 to 3.0 ppm, depending on the area and soils where it was grown. If a complete ration has a total copper level of seven ppm it would likely be inadequate in copper if an alfalfa containing three ppm of molybdenum was used for an extended period. This would necessitate raising the total copper level to 10 or 12 ppm. Some experimental work indicates that if the calcium to phosphorus ratio is greater than six to one the danger of calcium combining with copper increases and a possible border-line copper deficiency may develop. With excess calcium present the possibility of the phosphorus metabolism being disturbed in the presence of molybdenum is feasible and may cause the bones of the animal to become weakened. Why is this possible? As the pH of the feed is increased, molybdenum availability increases and copper availability decreases. Border-line copper deficiency is not acute in its development but rather appears gradually as the animal's normal reserves are lowered. Border-line deficiency is not related to a sudden change in ration, but is most often found where a long-continued feeding practice is in effect and the deficiency is unnoticed or non-apparent. Border-line deficiencies are often unnoticed in farm practice due to their slow development with very gradual changes. However, the border-line copper deficiency may manifest itself in the failure of animals to come into heat regularly or settle properly. If the copper level continues low in the ration over a long period or is rendered unavailable by the presence of excess molybdenum the percent of dead or weak calves increases.

Molybdenum follows the course of phosphorus in the animal body and is readily secreted in the milk. If milk with molybdenum present is fed to calves with a low or border-line copper reserve this may prevent the calf from developing normally or increase calf mortality. Another fact is that molybdenum may be transferred from the dam to the developing fetus through the placental membranes (35, p.265).

Fading of the hair-coat color is often one of the first symptoms of a border-line copper deficiency and may be confused with fading caused by sunlight.

Another possible border-line symptom is the failure of skin sores to heal, with a thickening of the skin in the vicinity of the sores. With increased copper levels the sores gradually improve and heal. However, it is not to be overlooked that such sores may be due to parasites or other diseases and this condition must be associated with other low copper symptoms.

EXPERIMENTAL STUDIES

Objectives of the Investigation

The objectives of the investigation were the determination of the importance, effect and value of copper or cobalt as supplements on the following:

1. scouring in beef and dairy cattle;
2. the relief and prevention of ketosis in dairy cattle;
3. the prevention of dairy animals from going off feed;
4. the condition of the hair coat such as shedding and pigmentation;
5. the growth of dairy heifers.

Experimental Procedure

Animals Used

For this work there was available the purebred Guernsey herd of 30 milking females, eight to ten dairy heifers which are raised annually as replacements for the dairy herd or sale purposes as breeding stock, and 25 to 40 head of beef animals wintered at the John Jacob Astor Branch Experiment Station at Astoria, Oregon. The number was variable from year to year but remained approximately the same throughout the winter feeding period.

Feeding and Handling of Animals

General Program

The winter feeding program followed at the Astoria station may be considered somewhat different from common practice in that almost a complete program of grass silage feeding as roughage is followed. The beef and dairy animals are carried on pasture from April to October each year. It is felt that the silage program is of such importance that it should not be discontinued or altered, especially since the general trend is for a more intensive silage utilization throughout the country. This program has come about due to unfavorable hay making conditions and a satisfactory means of preventing nutrient losses by other type of mechanical preservation. While following this program of home produced roughage utilization certain abnormalities have appeared and become accentuated.

Feeding of Animals

The primary roughage used for all classes of livestock during the winter feeding period is grass silage, produced locally at the station. The silage is composed of various grasses, primarily Alta Fescue, Meadow Foxtail, Perennial Rye Grass, and Lotus Uliginosus. A small volunteer sprinkling of Reed canary grass was present in addition to negligible quantities of volunteer white clover. The silage was made by wilting to an average moisture content of 65 to 75 percent moisture depending on weather conditions and ensiled with 65 to 75 pounds molasses per ton of green material.

Dairy Animals

The dairy herd was started in October 1946 on grass silage as the only roughage. Silage was fed five times daily, before and after the twice daily milking period and the fifth time in the morning after the barn was cleaned and the animals bedded down. At this time 100 pounds of dried beet pulp was also fed to the 30 cows. Silage consumption averaged 60 to 70 pounds per head per day throughout the barn feeding period. Cows were kept in the barn in regular stanchions except for a brief exercise period of one to two hours daily depending on weather conditions. At times, during inclement weather, they were not turned out for several days. The winter period in the barn varied somewhat from year to year depending on when the heavy rainy period started, either in October or November and was continued to sometime in April.

Several cows have made records of over 600 pounds of butterfat with silage as the only roughage. When high records are being made, one may generally anticipate some type of difficulty in a later lactation such as acetonemia or declining production. The condition of the animals in the milking herd generally could be classified as good. At times certain animals, particularly the younger ones, have not shed their winter coats as they should. The coats of the two and three year animals during the winter barn period will often be longer, heavier and thicker than the animals four or more years of age.

Until 1951 the cows were carried on non-irrigated "tideland" (muck soils) pasture for an average period of 170 to 190 days throughout the summer grazing period, day and night. The cows on pasture were rotated every two days using six pastures of approximately four acres each for 30 head. Late in the summer of 1951 irrigation was commenced. The age of pasture varies with the last seeding being made in 1947. The larger portion of two pastures is composed of meadow foxtail and has been in continuous production for 17 years without reseeding. The age of the other pastures would fall between these periods. The primary pasture grass used throughout is meadow foxtail, while two pastures contain considerable amounts of orchard and bent grass. Lotus Uliginosus is the principal legume although survival with heavy nitrogen application is hindered. White clover at certain times is found in moderate quantity.

Regular fertilizer applications are made which include lime, phosphate, nitrogen, solid manure, and liquid manure. The program would be classed as a good fertilizer program for the area.

The dairy herd concentrate mixture contained 14 to 14.5 percent crude protein as calculated by Morrison standards. The crude protein content of the silage as fed varied from four to five percent. Basically the dairy herd grain ration was composed of the following, with slight modification from time to time:

mill run	400 lb.
ground barley	100 lb.
rolled barley	200 lb.
ground corn	200 lb.
ground oats	300 lb.
rolled oats	400 lb.
ground wheat	100 lb.
linseed meal	100 lb.
soybean meal	200 lb.
steamed bonemeal	40 lb.
salt (iodized)	20 lb.
Vitamin D-2 (12,000,000 I.U.) ..	1/2 lb.

From January 1949 to June 1950 no Vitamin D was used in the basal herd ration with this item being handled in a different manner for Vitamin D work. Three pounds of magnesium sulfate have been included in each ton of dairy ration since the fall of 1950.

The exclusive silage feeding program was carried out for the following winter periods: 1946-1947, 1947-1948, 1948-1949. In the fall of 1949 this program was altered to include approximately five pounds of good quality alfalfa hay per head daily throughout the winter period with the rest of the forage ration being fed as silage and beet pulp. This program reduced the number of times silage was fed to four times per day and the beet pulp was continued as previously outlined. An average of one to two pounds of molasses was fed per head per day from the fall of 1947 till the winter of 1951. This changed when molasses became available for inclusion in the grain ration at the time of mixing. The rate of grain feeding varied depending upon the condition and milk flow of the animal. Generally grain was fed at the rate of one pound of grain to two and one-half to three pounds of milk per animal. Seldom did it decline to the one to four or five pound ratio. Dry cows were fed four to six pounds of grain per day, depending on condition, throughout the dry period.

Replacement Dairy Heifers

The dairy heifers were raised in individual pens on limited whole milk averaging five pounds per head per day and started as rapidly as possible on a grain ration of one-third rolled oats, one-third rolled barley, and one-third high protein calf ration supplemented with two percent bone meal, one percent salt, and adequate Vitamin D supplement. A good quality station grown grass hay was provided ad lib. The calves were kept on this ration until three to four months of age when a change-over was made to the regular dairy herd grain ration. At this time they were moved to a large pen until six to eight months of age, after which they were moved to an open shed type of housing where pasture is available and they might run out winter and summer. During the winter these animals were fed once daily all the silage they would consume throughout the day. Three pounds per head daily of the regular 14.5 percent dairy herd ration was allowed the dairy heifers during the winter months until the pasture was well developed in the spring. At times it has been necessary to feed 12 to 18 month old heifers throughout the summer in order to maintain growth even though plenty of pasture was available. Hay made from Astoria Bentgrass was available for the heifers at all times throughout the winter and summer. This hay is fine stemmed with few leaves and has a crude protein content varying from five to seven percent. Its quality as hay, although not often damaged by weather, could not be classed as good.

Beef Animals

The beef herd wintered at the station consisted of replacement heifers usually ten to fifteen in number which were brought to the station at weaning time in the fall and were to be used as replacement breeding stock in the beef herd. Additional cows were brought in from fall pasture after being grazed some 35 miles distant on logged off lands throughout the summer grazing period. The total number wintered was 25 to 40. These were fed silage throughout the winter feeding period excepting a brief period in the spring of 1950 and 1951 when surplus potatoes were fed. During the winter of 1950-1951 approximately two pounds per head of ground mixed wheat and barley were fed daily. In 1951-1952 this was raised to a three pound level and fed for a four month period.

Each year the replacement yearling heifers in addition to a few cows are pastured throughout the summer grazing period on Astoria Bentgrass growing on unimproved, non-fertilized "tideland" heavy muck soils. Bone meal and salt were provided as supplements.

Record Keeping

All milking females in the dairy herd were on official advanced registry test each lactation. Daily milk records were kept with a butterfat test being made monthly. All cows were entered for 305 day records and these were adhered to unless an animal failed to conceive. The record was then extended to 365 days. Two months dry period was generally allowed between lactations.

No growth weights or cow weights were kept on any animals due to inadequate scale facilities and insufficient help. A record of acetone tests using sodium prusside was begun in 1949-1950 and has been continued.

All doses of copper and cobalt administered to the milking herd since 1949 have been recorded.

Feed Analyses

Analyses were not made of the grain rations, beet pulp or minerals. In the spring of 1952 several samples of cane feeding molasses were analized in order to determine if this was a possible source of copper found in the 1951-1952 silage. Exploratory but not complete and comprehensive analyses were made of the hays, pastures, and silages consumed.

Worm Determinations

Checks were not made for worms in either the milking dairy herd or the dairy heifer group. Scouring was not noted in the latter at any time.

Beef animals which were scouring or in poor condition were checked for worms at various times. A saturated saline solution was used to determine the worm egg population in fecal specimens.

Mineral Supplement

A stock solution of cobalt sulfate was used. This was made by dissolving 24 grams of cobalt sulfate in one gallon of water. Eight fluid ounces, the maximum dosage used, would provide 1.5 grams cobalt sulfate.

Until March 4, 1952, a stock solution of copper sulfate containing 29 grams of copper sulfate in one gallon of water was used. This formulation was used to provide 3.6 grams of copper sulfate in 16 fluid ounces for an adult animal.

After March 4, 1952, the stock solution for copper sulfate was changed to contain 72 grams of copper sulfate in one gallon of water. Sixteen fluid ounces (one pint) contained a dosage of nine grams of copper sulfate which was used as a maximum dose for an adult animal. Davis (38, pp.1-5) administered 12 grams of copper sulfate to a 1,000 pound animal every ten days for an indefinite period without toxic symptoms.

In the fall of 1950 three pounds of magnesium sulfate was included in each ton of grain as a possible protection against "grass tetany" (59, pp.618-619)(79, pp.216-219) and as a possible aid in the reduction of acetonemia (56, pp.247-248).

The mineral mixture used for beef cattle supplementation was made up of the following: 200 pounds steamed bone meal, 100 pounds dolomitic limestone containing 25 percent magnesium carbonate, six pounds copper sulfate, and one ounce cobalt sulfate.

RESULTS AND DISCUSSION

Soil Conditions

The soils of the Oregon coastal region are quite variable (99, pp.7,77-79). They include: (1) wind-blown sands; (2) upland or hill soils which are of a compact clay loam derived from sandstone and shale; (3) flood plain soils which are composed of alluvial materials derived from marine deposits with drainage usually a problem--many of these soils are under dike; (4) organic soils, which are composed of peats; (5) silty clay loams, with and without gravel subsoils--these are old valley fillings and stream bottoms.

The pH of the soil usually varies from a low of 4.02 to a high of 5.8. Most soils will fall within a range of a pH of 4.5 to 5.3.

Variable rainfall is found up and down the coastal region with the Astoria vicinity averaging about 75 inches annually. Most of this rainfall occurs between the months of October and March.

Scours

Copper sulfate alone was effective in controlling scours in animals from the spring of 1949 until April 1950. During this period, recorded cases responded to this treatment. The amount of copper sulfate used was 3.6 grams in one pint of water, given as a drench. A few cases required more than one dose when the scouring did not stop after the second day. However, repeat dosing effected a complete cure in all cases. After April 1950, drenching treatment was changed to combine cobalt and copper administration.

By continued use of copper sulfate and cobalt sulfate drenches it has been found that scours can be controlled in most animals. When the minerals are made available in the feed, difficulty is avoided. Local livestock men continue to come to the station to obtain information and treatment recommendations and very few cases fail to respond to treatment. Cures have been effective when some veterinarians have given up all hope with other control measures.

Scours Treatment

If an animal has been scouring for a long period and is found to be emaciated and rundown before treatment is commenced a check should be made to eliminate the possibility of worms being a contributing factor. If worms are diagnosed as being a contributing factor, proper prophalactic measures should be taken in addition to copper therapy.

Scours many times may be the result of other disorders such as Johne's disease, foreign bodies, viruses, overfeeding, and other abnormal conditions. However, if the scours appear near calving time, particularly in young animals at first calving, or a number of animals commence to scour while on lush spring or autumn grass, one should suspect copper deficiency.

"Winter scours" in milking dairy cattle have also, generally, been controlled successfully by use of copper and cobalt.

The stock solutions of copper and cobalt found under mineral supplements can be used for scours treatment. Administration is by drench and the copper and cobalt may be mixed together after the quantities are measured.

Treatment: (for adult cattle)

1st day: 16 fluid ounces copper sulfate (9 gm $CuSO_4.5H_2O$)
2 fluid ounces cobalt sulfate (750 mg $CoSO_4.7H_2O$)

2nd day: no treatment

3rd day: repeat first day if scours have not stopped

4th day: no treatment

5th day: treat with one-half the quantities used on the first day

Continue the fifth day treatment every other day until scours have stopped. Whenever the scours are arrested the every other day treatment should be discontinued and a weekly treatment using the fifth day dosage should be used for a period of three to four weeks or longer if the animal has been scouring heavily over a long period. Sometimes the scouring will reappear after therapy is discontinued. If so, re-treatment will be necessary and the fifth day treatment should be used at weekly intervals for a longer period.

If yearling cattle are to be treated the quantities shown under treatment for adult cattle should be reduced by one-half and the schedule followed as previously shown.

In the event of winter scours in dairy cattle, blood is often passed in the feces and mineral oil (one quart) is helpful in reducing the irritation in the intestinal tract if desired. However, mineral oil is difficult to administer by drench and care should be used.

A word of caution should be extended. Copper is a poison when used in excessive quantities and this should be kept in mind. Do not overdose or increase the quantities given on the premise that if a little is good a whole lot will be better.

It is often helpful to provide dry feed, such as hay, in order to effect a more rapid cure.

Acetonemia

During the spring of 1948 and 1949 before copper and cobalt treatment was used, four animals in the station herd were affected by acetonemia in an acute form. Symptoms included: lack of appetite, sharp reduction of milk flow, rapid loss of body weight and listlessness. One animal showed nervous muscle spasms in the right flank area. The characteristic acetone odor was not always apparent in the milk and breath. The cases generally occurred shortly before or after parturition and the animals were in good condition. The onset of acetonemia, generally, took place following two or three years of high production. Other cases have probably occurred in this herd before the dates indicated, but the condition was not recognized as such.

These animals were treated by the local veterinarians, using various methods. Treatment resulted in improved appetite, increased milk flow and general return to health.

Commencing in January 1950, a total of 18 cows showing acetonemia symptoms were successfully treated by the use of copper and cobalt.

All of these cases were not checked by the sodium prusside indicator method, but in seven cases that were checked the strong deep purple (+ + + +) reaction was changed to a light pink (+ + or +) or negative (-) reaction. Spot checks on animals previously recovering from acetonemia in response to copper and cobalt treatment showed a light pink or negative reaction as determined by the sodium prusside test.

Acetonemia Treatment

Animals often went off feed for no apparent reason. When this occurred they were given varying amounts of cobalt sulfate in order to keep them eating. If an animal scoured while undergoing cobalt treatment, she was given a solution of copper sulfate, generally 16 fluid ounces containing 3.6 grams of copper sulfate. This quantity has been raised to nine grams since March, 1952. If one treatment did not stop the scouring within one or two days a second dose was given.

Cobalt alone did not give complete recovery from acetonemia, but it seemed to help keep the animals from going completely off feed. When copper was administered with cobalt an improvement was noted and a change from a positive to negative reaction was obtained as indicated by the sodium prusside urine indicator test. Davis (38, pp.1-5) believes that cobalt either acts as a catalyst or has some unknown beneficial effect on the utilization of copper. This could have been possible under these conditions. Several times animals receiving periodic cobalt treatment started scouring. Such scouring was stopped by drenching with copper and the animal recovered from acetonemia much more rapidly.

If treatment with copper and cobalt was started during the dry period good response was obtained, as exhibited by improved appetite and weight gains.

Two mature cows received massive oral doses of cobalt sulfate over a sixty day period with each animal receiving approximately 54 grams of cobalt sulfate. The animals showed no apparent toxic effects (44, pp.326-330) such as lacrimation, salivation, dyspnea, incoordination, or urination. These animals showed no decrease in milk flow or discomfort.

The following treatment for acetonemia has been developed with effective results for the Clatsop County area: Cobalt stock solution (pink)--dissolve 24 grams of cobalt sulfate in one gallon of water; Copper stock solution (blue)--dissolve 72 grams of copper sulfate in a second gallon of water;

Treatment: (adult cattle)

1st day:
16 fluid ounces copper sulfate (9 gm $CuSO_4.5H_2O$)
8 fluid ounces cobalt sulfate (1.5 gm $CoSO_4.7H_2O$)
1/4 pound magnesium sulfate (epsom salts)

2nd day: no treatment

3rd day:
16 fluid ounces copper sulfate (9 gm $CuSO_4.5H_2O$)
8 fluid ounces cobalt sulfate (1.5 gm $CoSO_4.7H_2O$)

4th to 9th days: no treatment

10th day:
8 fluid ounces copper sulfate (4.5 gm $CuSO_4.5H_2O$)
8 fluid ounces cobalt sulfate (1.5 gm $CoSO_4.7H_2O$)

Repeat the tenth day treatment once a week for three to four weeks. This may be continued longer if desired.

After measuring out the quantities needed from the stock solutions they may be added together in the same container for drenching purposes.

Effect of Copper and Cobalt on Lactation

Table IV shows the actual uncorrected milk and butterfat production records of the three cows presented in Figures 1, 2, and 3. The average daily milk production for each month was used in the figures for each lactation. Treatments indicated are for the supplement used and do not show the amount of copper and cobalt sulfate used. This indicates the influence of the cobalt and copper treatments which are representative of the results obtained on other animals by copper and cobalt administration.

It should be noted that these animals in all instances started and maintained their production higher than preceding lactations. The decline in production was rather rapid in some instances within a month or two after treatment was discontinued. The carryover effect in some cases was for a longer period of four or five months when treatment had been maintained over a longer period. The decline is often more rapid than for Eckles normal (45, p.381). Earlier records on these animals have been deleted from the charts in order to present a clearer picture. Most animals, however, in the Astoria herd as a general rule have maintained a more uniform

TABLE IV.

Actual Production Record of Animals in Figures 1, 2, and 3

Calving Date	Number of Days in Record	Pounds Produced Milk	Pounds Produced Butterfat
	Hildegard Born 2-14-43		
12-29-46	305C*	9,992	492
2-20-48	305C	6,441	334
3-16-49	305C	5,848	292
3-15-50	265**	7,221	349
	Ardith Born 2-12-43		
1-19-46	305C	11,214	583
1-14-47	305C	10,329	546
1-1-48	305C	11,116	592
12-17-48	365C	8,588	454
2-16-50	305C	8,859	449
3-9-51	227 da ***	8,517	416
	Peggy Ann Born 2-6-43		
3-29-46	305C	9,730	508
5-17-47	365	10,524	535
8-15-48	365	10,313	510
12-24-49	305C	11,141	528
1-12-51	305C	9,563	451
2-22-52	365	12,202	568

* C denotes that the animal met calving requirements for the record
** 529 milkings in this record; terminated due to low production
*** died of pneumonia

Nutritional Studies with Copper and Cobalt

Hildegarde born 2-14-43

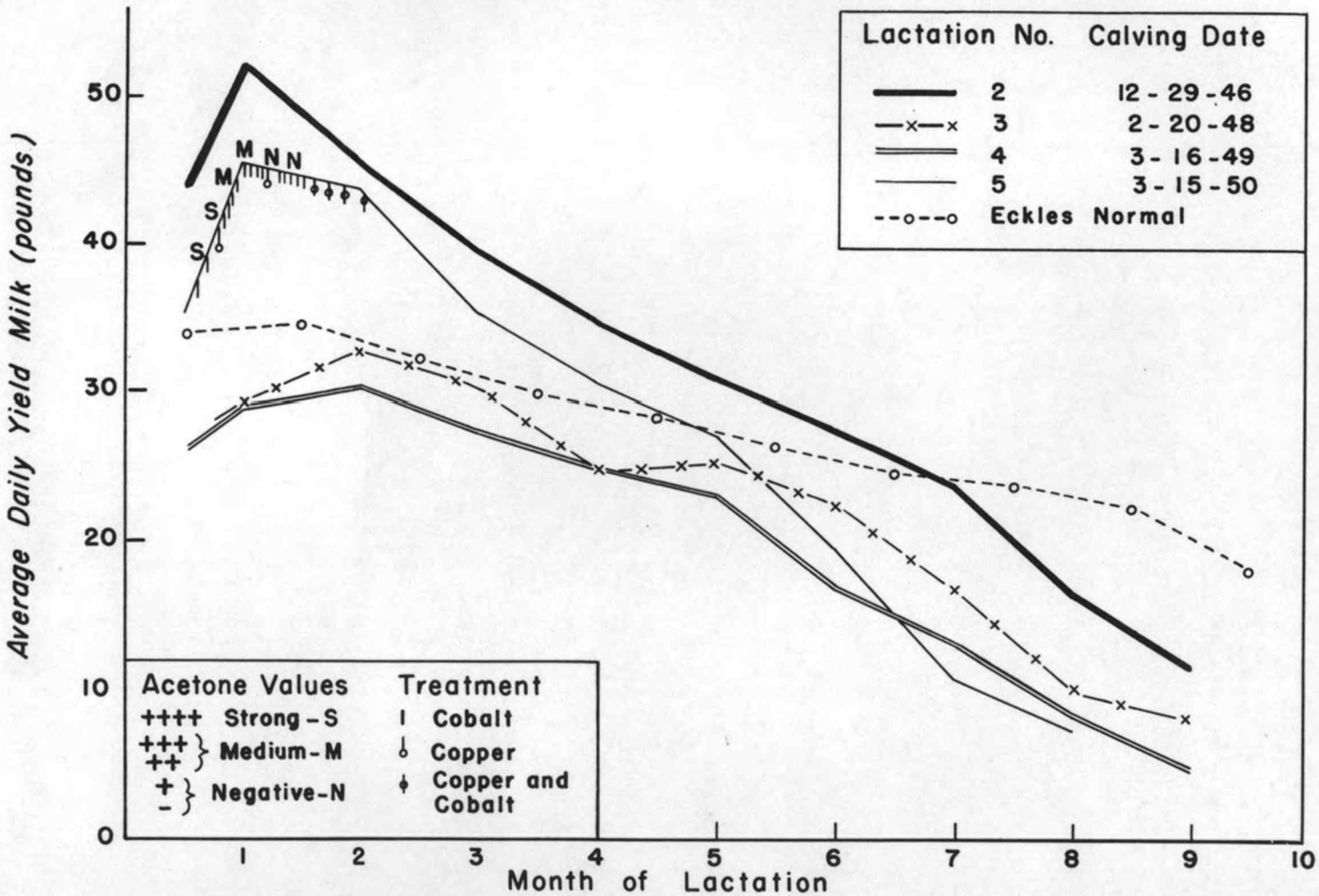
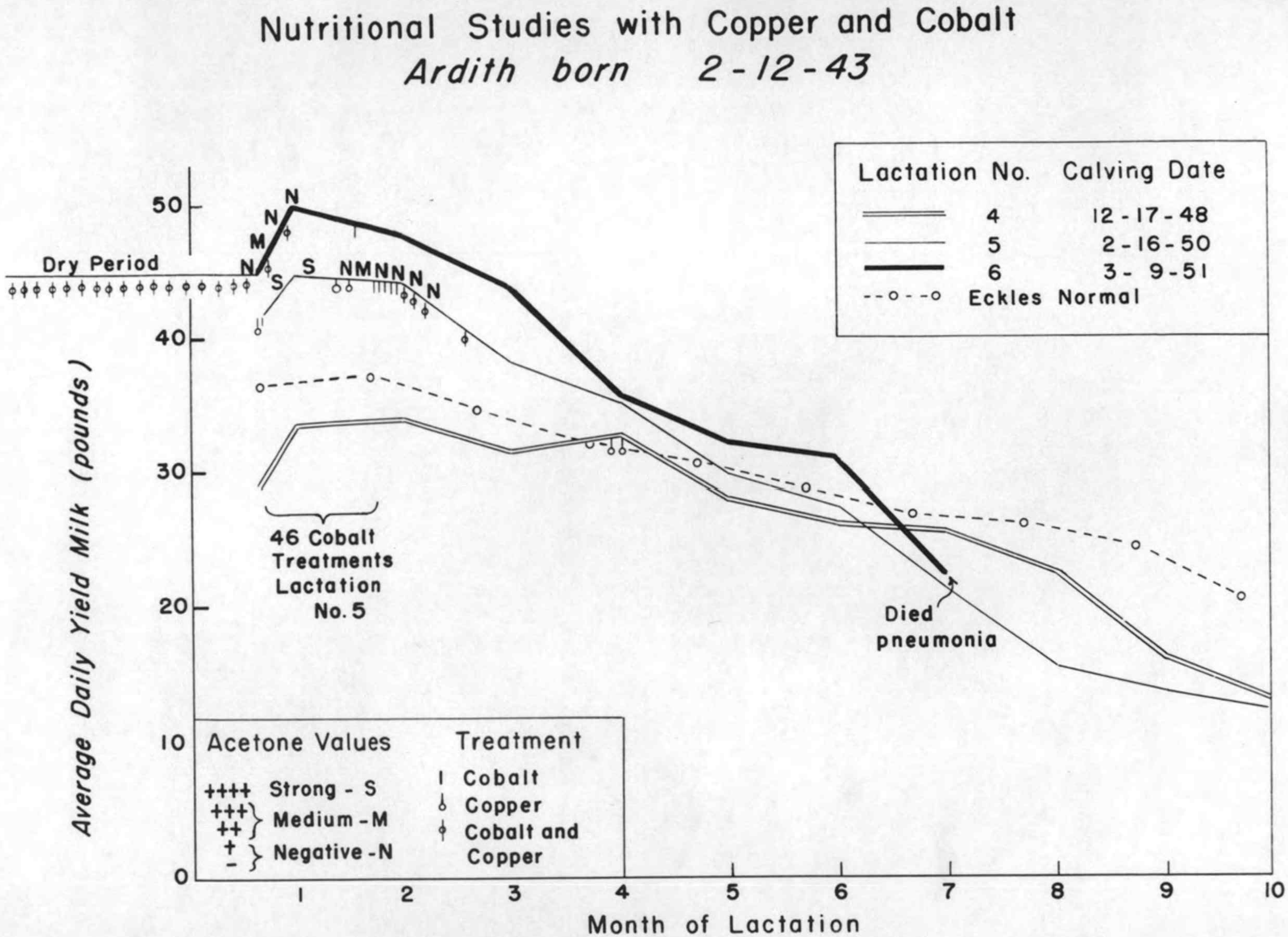


Figure 1.



Nutritional Studies with Copper and Cobalt
Ardith born 2-12-43
Lactation No. Calving Date
4 12-17-48
5 2-16-50
6 3-9-51
Eckles Normal
Dry Period
46 Cobalt Treatments Lactation No. 5
Died pneumonia
Acetone Values
++++ Strong - S
+++ ++ Medium - M
+ − Negative - N
Treatment
Cobalt
Copper
Cobalt and Copper
Average Daily Yield Milk (pounds)
Month of Lactation

Figure 2.

Nutritional Studies with Copper and Cobalt

Peggy Ann born 2-6-43

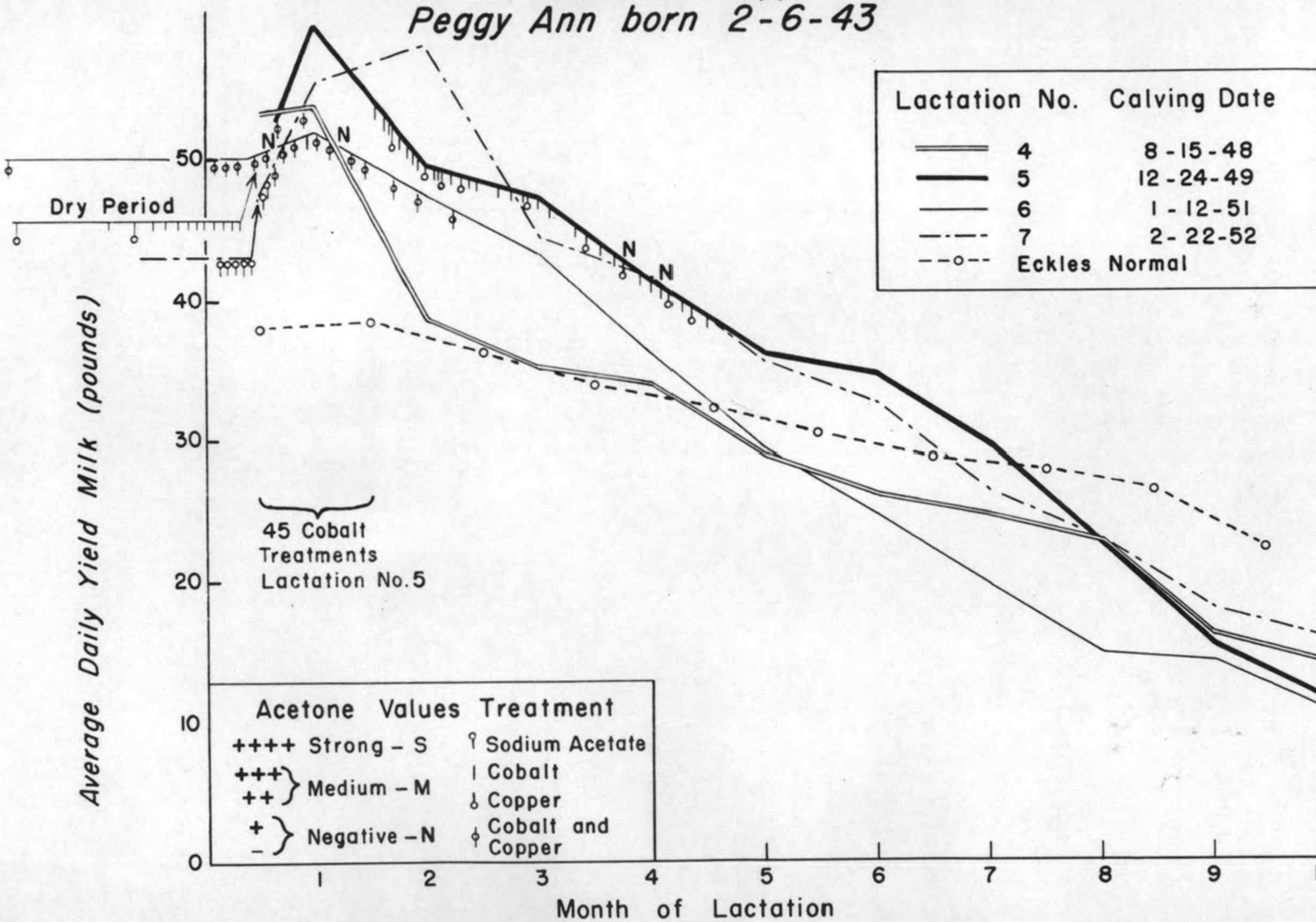


Figure 3.

level of milk production during the last part of their first lactation.

The cow, Tideland Peggy Ann, Figure 3, at the start of her seventh lactation showed acetonemia symptoms as exhibited by loss of appetite and flesh. Peggy calved on February 22, 1952. On the 23rd, the day after calving, sodium acetate feeding was commenced and fed daily at the rate of one-half pound per day to see if this would improve her appetite. From March 1st to 4th the acetate feeding was reduced to one-fourth pound daily. As long as this animal was receiving the acetate her appetite appeared to be normal as indicated by improved consumption of grain and silage. On March 4, eleven days after calving, this animal went off feed and started scouring. At this time the acetate feeding was discontinued and she was drenched with nine grams of copper sulfate and 750 mg of cobalt sulfate. Three days later she was still scouring and she was again treated with nine grams of copper sulfate and 750 mg of cobalt sulfate. Twenty-four hours after the second dose scouring ceased and appetite improved. Milk flow went from a low of 39.9 pounds of milk after the second copper-cobalt treatment to 51.1 pounds seven days after treatment. Fifteen days after the last copper-cobalt administration Peggy produced 63.3 pounds of milk.

A trial was started using Peggy Ann to determine the beneficial or detrimental effects on long-time copper and cobalt feeding. On May 8, 1952, starting with the ninth week of this lactation (seventh) Peggy was drenched weekly with 4.5 grams of copper sulfate and 561 mg cobalt sulfate until the fourteenth week and the weekly dosage was changed to 4.5 grams copper sulfate and 187 mg cobalt sulfate. This dosage was continued until the twenty-first week and treatment was then changed to 1/4 gram copper sulfate daily with six mg of cobalt carbonate daily until her lactation was completed. After regular treatments of cobalt and copper were started in the ninth week, this animal showed improved coat condition, fleshing, and general appearance. Peggy's production during this treatment period is shown in Table IV and Figure 3 under the February 22, 1952, calving date.

Lactation Study

A comparative study, Table V, between lactations of all females in the Station herd with successive lactations was made in order to note the decline, if any, between the first and later lactations. All records, which were made on twice a day milking, were converted to 305-day mature equivalent basis for comparison. These are unselected lactations and include every animal in the herd between the period of spring 1946 and April 1952 with two or more records. Under the 30 lactations compared as a first lactation group, 24 animals started with their first lactation. Three animals were included under the first lactation group starting with the second lactation, one with her third lactation, and two with their sixth lactation. The animals included all had a previous normal lactation, however. The lactations not included were during the war period when a tester was not available. The inclusion of these animals would

TABLE V.

Lactation Comparison Between Station Herd and Willamette Valley Herd

	Sta. Herd	Willamette Valley Herd	Sta. Herd	Willamette Valley Herd	Sta. Herd	Willamette Valley Herd	Sta. Herd	Willamette Valley Herd	Sta. Herd	Willamette Valley Herd
Number of lactations compared	30	32	17	16	12	11	5	5	2	2
Lactation No. Lactation No. compared	1st 2nd	1st 2nd	1st 3rd	1st 3rd	1st 4th	1st 4th	1st 5th	1st 5th	1st 6th	1st 6th
Avg. lbs. B.F. (M.E.*) First lactation	506	484	514	516	533	551	582	557	643	498
Avg. lbs. B.F. (M.E.*) of compared lactation	467	479	439	506	423	499	414	514	488	494
Avg. lbs. B.F. difference between lactations	39	5	75	10	110	52	168	43	155	4
Net loss between lactations compared	1213	157	1289	158	1318	564	847	214	309	9

* Mature equivalent age conversion factors U.S.D.A. Bureau Dairy Industry

seem to have no material influence in changing the first mature equivalent average as many of the animals had a higher mature equivalent for their first lactation than their second lactation, while other animals were the reverse. It was found that animals further along than the second lactation usually had already started a steady decline from year to year.

For progressive comparison in later lactations the records of the animals compared were segregated from the original group and their first lactation was re-averaged for each successive comparison.

For example, there are 30 animals in the station group having completed two lactations. Their first lactation was averaged and their second lactation was averaged separately and then compared for difference. Out of the 30 animals in this group, 17 have completed three lactations. These 17 were treated as a group and their first lactation was again added, averaged and compared with their third lactation which was added together and averaged. Each group of comparisons were developed in this manner.

A similar study was made of a Willamette Valley herd which is located approximately 60 to 70 miles inland from the coastal area. The herd is of similar breeding to the station herd and traces to the same original blood lines. The herd is considered to be under good care and management with a maximum utilization of home produced feeds and their records were made under a comparable 305-day basis with twice daily milking. The records are unselected, taken as they could be located from the advanced registry herd books of the

American Guernsey Cattle Club. It has been a practice in this herd also to run every animal on test. All records of the animals in this group started as two year olds except one, and this animal was five years old. Comparative decline in lactations within the two herds is presented in Table V.

Ten out of the 12 animals in the station herd under the first and fourth lactation comparison of Table V had to be treated for acetonemia or an "off feed" condition at one time or another.

Statistical Analyses

Table VI shows the original mature equivalent butterfat production data of each animal under the various designated lactation numbers used in a statistical comparable study. These are the animals shown under the first and fourth lactation groups in Table V. This group was selected as representative. By selecting this group it was felt that the number of animals available would be more indicative for the greatest number of lactations.

The results of a statistical analysis on the 12 cows in the station herd and 11 cows in the Willamette Valley herd are shown in Tables VII and VIII. The station herd shows a significant decline in all later lactations at the five percent level as compared to the initial average mature equivalent of 533 pounds of butterfat. The Willamette Valley herd shows no significant decline at the five percent level as compared between the initial lactation and later lactations except the fourth lactation which was the only lactation showing a significant drop.

TABLE VI.

Original Mature Equivalent Butterfat Production Data for Statistical Analyses on Lactation Decline

Cow Number	1	2	3	4
		Station Herd		
1	616	670	453	527
2	653	583	508	569
3	531	421	393	404
4	576	487	446	528
5	452	300	420	353
6	670	583	605	454
7	467	446	385	333
8	528	340	292	349
9	517	407	487	330
10	445	403	372	382
11	483	399	409	326
12	462	472	478	527
Mean	533.3	459.2	437.3	423.5
		Willamette Valley Herd		
1	503	554	514	501
2	494	595	605	572
3	514	620	561	547
4	659	592	571	617
5	617	556	572	593
6	545	462	539	519
7	589	563	576	506
8	677	618	635	494
9	338	394	395	282
10	504	514	430	467
11	621	488	400	399
Mean	551.0	541.4	527.0	499.7

TABLE VII.

Analysis of Variance Between Initial Lactation and

Succeeding Lactations on Mature Equivalent Butterfat Records

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F
		Station Herd		
Cow	11	262,840.2	23,894.5	
Lactation	3	86,152.3	28,717.4	10.03
Error	33	94,524.3	2,864.3	
Total	47	443,516.9		
		Willamette Valley Herd		
Cow	10	221,177.5	22,117.7	
Lactation	3	15,466.7	5,155.5	1.96
Error	30	79,068.2	2,635.6	
Total	43	315,712.5		

TABLE VIII.

Mean Production and Mean Difference Between Initial Lactation and

Succeeding Lactations on Mature Equivalent Butterfat Records

Lactation No.	1	2	3	4
		Station Herd		
Mean	533.3	459.2	437.3	423.5
Difference		74.1*	96.0*	109.8*
LSD .05 = 44.57				
		Willamette Valley Herd		
Mean	551.0	541.4	527.0	499.7
Difference		9.6	24.0	51.3*
LSD .05 = 44.69				

* Significant at the 5% level

Analyses of Feeds

Tables IX and X show various feed analyses of samples taken from time to time over the period from March 1949 to June 1952. It is recognized that they are not complete but may show a trend. The samples were not taken exclusively from the station lands. A few are from other farms in the coastal vicinity near Astoria. All samples to date show the following: 26 cobalt values for the Astoria area have a low of 0.01 ppm to a high of 0.73 ppm with a mean of 0.25 ppm; 26 copper values have a range of 1.7 ppm to 17.8 ppm with a mean of 7.0 ppm; 22 molybdenum values range from 1.1 ppm to 8.3 ppm with a mean of 3.5 ppm. All analyses are on dry matter basis.

In Table X the first five samples were taken May 8, 1952, when 24 head of beef cows with their calves were placed on this field of approximately 24 acres for the summer grazing period. The grass averaged four to eight inches in height at that time. A summary of these five analyses shows the following: cobalt--0.01 ppm to 0.03 ppm, with a mean of 0.018 ppm; copper--3.0 ppm to 7.6 ppm, with a mean of 5.38 ppm; molybdenum--1.1 ppm to 2.5 ppm, with a mean of 1.96 ppm.

This pasture at the particular time the samples were taken could be classed as cobalt deficient, on the border-line of being copper deficient, and having sufficient molybdenum under certain conditions to cause complicated copper deficiency. However, the status of this pasture might, conceivably, change materially later in the season. It was noted that several of the beef animals

TABLE IX.

Forage Analyses*, Astoria and Vicinity

Serial No.	Description	Crude Protein %	Ca %	Mg %	P %	Co ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm
H10725	Bent grass 4/3/50	21.15	.49	*	.30	*	*	*	421	6.5
H10726	Bent grass 4/3/50	22.43	.66	*	.39	.11	9.6	160	251	8.3
H11526	Velvet and bent grass hay	4.95	.23	*	.10	.18	1.7	59	178	2.8
H9564	Bent grass hay 3/2/49	7.03	.26	.21	.20	.30	8.2	85	407	2.2
H10384	Bent grass hay 11/15/49	5.95	.14	*	.15	.18	4.6	88	412	2.1
H10396	Tideland Pasture 11/15/49	23.15	.27	*	.52	.23	8.9	231	139	7.1
H10397	Dairy herd pasture 11/15/49	18.35	.27	*	.44	.17	8.4	267	234	3.3
H10398	Tideland pasture 11/15/49	22.15	.19	*	.39	.54	10.7	373	192	3.8
H10399	Hospital tideland 11/16/49	12.13	.19	*	.28	.73	6.4	314	668	3.0
H11779	Pasture hospital tideland 11/7/50	*	*	*	*	.54	6.0	208	*	4.2
H11778	Pasture 11/7/50	19.75	.65	.24	.41	.23	11.6	378	*	3.9
H11780	Chopped hay 11/7/50	9.10	.85	.23	.23	.18	5.4	136	*	3.0
H9565	Silage 3/2/49	12.70	.36	.29	.27	.73	8.7	*	*	*
H9566	Silage 3/2/49	12.30	.43	.30	.25	.63	8.3	*	*	*
H13995	Silage 3/27/52	*	*	*	*	.28	4.4	686	*	*
H13994	Silage 3/27/52	*	*	*	*	.54	17.8	611	*	*
H12155	Alfalfa hay 2/6/51	17.40	1.78	*	.19	.06	3.6	164	30	*

* Analyses were not made

** Analyses by J. R. Haag, Agricultural Chemist

TABLE X.

Forage Analyses, May 8, 1952*

Serial No.	Description	Prot. %	Ca %	Pho %	Co ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm
	Hospital Tideland (Muck Soil)								
16038	Alta Fescue	10.10	**	**	0.02	3.0	44	80.7	1.1
16039	Unknown, Wet End	23.02	0.27	0.32	0.01	7.6	227	142.5	2.5
16040	N.Z. Orchard, West End	11.50	0.29	0.18	0.03	5.4	74	130.2	1.6
16041	Bent, N.E. Sector	**	**	**	0.01	5.4	78	272.5	2.4
16042	Meadow Foxtail, 75 yd. west of road	15.25	0.37	0.21	0.02	6.0	90	106.6	2.2
	Upland (Melbourne Series)								
16043	White Clover	25.45	1.51	0.35	0.05	4.9	185	35.9	2.8
16044	Lotus Major	29.92	1.02	0.44	0.20	4.9	569	56.9	1.6

* Analyses by J. R. Haag, Agricultural Chemist
** Analysis was not made

pastured on this field during the summer period showed scouring symptoms and unthriftiness while others maintained good health and good condition.

As shown in Table IX, the comparative copper contents for silage samples H9565 and H9566 with values of 8.7 ppm and 8.3 ppm respectively as compared to the copper content of 17.8 ppm for sample H13994 is worthy of note. These are silages from the Astoria Station taken in 1949 and 1952. The ensiled material was taken from the same fields each year with no copper added to any field at any time. The only key to the possible rise in copper content for the sample H13994 lay in the varying content of the copper in the cane molasses which was used as a preservative. Three cane molasses samples were taken in May 1952 and another in December 1952. These samples were not from the molasses used in the silo in 1952, but were taken during the silage making season and are from the same scource as the molasses used in making silage at the station. The cobalt and copper contents for these samples are presented in Table XI. The values found leave little doubt as to the source of the higher copper value. It has recently come to our knowledge that a concentrated solution of copper sulfate is used in industry to scour tank trucks, tank cars, storage tanks and ship holds. This is done to remove slime, sludge, and molds, and to hold down bacterial growth. When this practice was started is not known.

It is interesting to note that silage sample H13995 is from a farm where acetonemia and off feed conditions were experienced by the operator and the silage was made without preservative.

TABLE XI.

Molasses Analyses*

Serial No.	Date	Description	Co ppm	Cu ppm	Iron ppm
16697	5-8-52	Cane Molasses, top car	2.32	33.4	2820
16698	5-8-52	Cane Molasses, botton car	2.21	32.5	2722
16699	5-8-52	Cane Molasses, LOCODA Storage Tank	2.49	25.8	2864
17615	12-16-52	Molasses, LOCODA	2.14	20.7	463

* Analyses by J. R. Haag, Agricultural Chemist

Liver Analyses

A wide scale program of liver analyses has not been instituted to date due to lack of development of a biopsy technique at the station and availability of animals for that purpose.

In December 1952 three animals were removed from the dairy herd as non-breeders and this presented an opportunity to obtain liver samples from these animals. The results are given in Table XII. One animal had been given copper sulfate supplement at the rate of one-half gram per day for a three month period. Another had been supplemented at the rate of one-fourth gram for the period while a third animal had not been supplemented. A fourth sample was obtained at the same time from the Oregon State College dairy herd and she had not received trace element supplements.

The copper levels for the three Astoria dairy animals reflect the treatment given while the OSC animal had a higher copper value than any of the Astoria animals. According to New Zealand standards the control animal of the Astoria herd would be classed as copper deficient. This animal showed visible copper deficiency symptoms including long hair and a "tight-hided" condition.

The three beef animals shown in Figure 4 were scouring in the late fall of 1950 when taken off the hospital tideland (muck soil) pasture of native Astoria Bentgrass. The only feed supplements available had been bonemeal and salt. It will be noted that one animal had already reached the depigmentation stage. These animals

TABLE XII.

Iron and Copper Content of Astoria Branch Station Cattle Liver*

Sample	Treatment	Fresh Liver Weight	Percent Moisture Content	Cu** ppm	Fe** ppm	Remarks
Ada H-17329	1/2 gm $CuSO_4$ per day	23 lbs.	71.7	324.0	317	Normal coat
Annamae H-17330	1/4 gm $CuSO_4$ per day	19 1/2 lbs.	71.1	213.4	388	Normal coat
Larkspur H-17331	Control	16 1/2 lbs.	70.5	44.7	375	Long hair "Tight" hide
OSC Jersey #219 H-17332	Untreated OSC Dairy Herd	13 1/2 lbs.	70.9	395.5	461	

* Analyses by J. R. Haag, Agricultural Chemist
** Based on dried liver sample

Figure 4. Coat color changes in beef animals.

were placed in a separate pasture and were fed grain containing a mineral supplement with six pounds of copper sulfate and one ounce of cobalt sulfate. All animals ceased scouring in a short time. The depigmented animal returned to a dark red color several months later.

Four animals, one a two year old, in a grade Holstein herd at Seaside, Oregon, had premature graying around the eyes and one case showed graying in the black areas of her body. Several animals in this herd were showing considerable scouring. Weekly treatment using a drench containing four and one-half grams of copper sulfate and 750 mg of cobalt sulfate caused the grayness to return to a normal black in three months. The scouring animals were cured by the copper and cobalt administration.

It has been noticed at times that animals transferred from the dairy herd at Astoria to other regions have become decidedly darker in color. Visitors sometimes have objected to the lightness of the darker coat color in the Guernsey cattle at the Astoria Station and have not been interested in purchasing breeding stock for that reason.

Coat Changes--Cobalt Supplementation

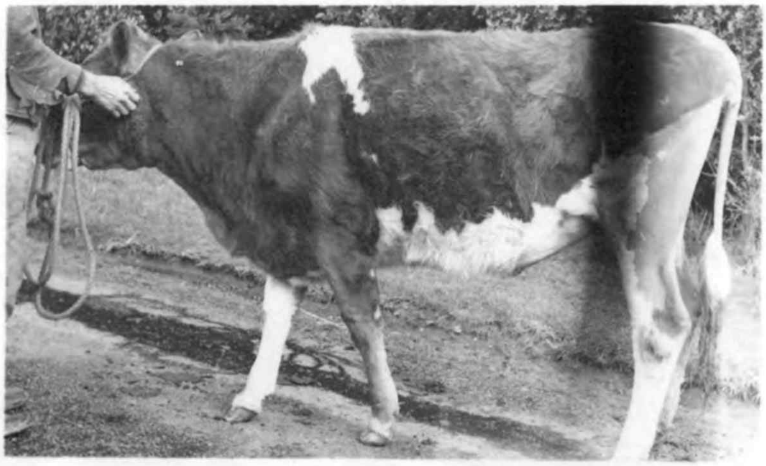
In late December 1950 nine first calf cows in the milking string were not shed out as compared to the older animals in the milking herd although they had received the same feed and care for from seven months to a year. Six animals were fed cobalt sulfate as a drench at regular intervals in four fluid ounce doses containing 750 mg cobalt sulfate per dose. The other three were used as controls. Total cobalt sulfate dosages were as follows: December, 750 mg; January, 8,900 mg; February, 4,450 mg; March, 3,000 mg; and April, 750 mg. At the end of the four month period no differences could be noted between the controls and the treated animals in rapidity of shedding and in general condition.

<u>Coat Changes--Copper, Cobalt Supplementation</u>

In the fall of 1952 eleven animals two to three years of age were brought into the milking herd as replacements. Five of the animals were fed a grain ration containing copper sulfate and cobalt sulfate starting September 4, 1952. Two animals received one-half gram of copper sulfate along with 12 mg of cobalt carbonate, while three received one-fourth gram of copper sulfate along with six mg of cobalt carbonate. Six animals were maintained as controls and received an identical ration except for the copper and cobalt. All animals in the supplemented group shed out properly without long hair and showed a loose pliable good quality skin condition. Five of the six control animals stayed long-haired and had no luster to their coats. Four of the six were "tight-hided" and with spring shedding are considerably lighter in color with their new coats. The supplemented animals with spring shedding continue to be of the same dark hue carried throughout the winter.

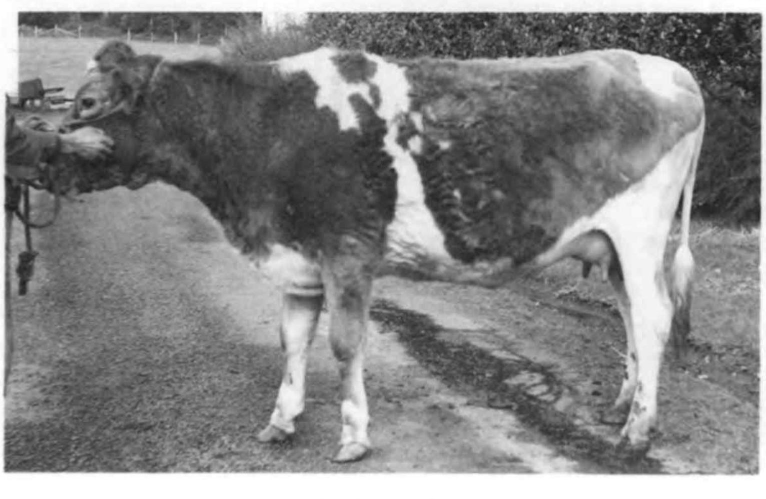
Swollen Leg Joints

In Figure 5 are shown three animals, two with swollen knees and legs while the third animal's legs are normal. These pictures were taken on December 29, 1950. Cow B with normal legs was three years old and had been in the barn for two months stanchioned on a concrete floor with chopped Lotus straw for bedding. She was fed the normal herd ration without Vitamin D supplement. Animals A and C were brought in from the heifer lot as "springing" heifers December 15, and after standing on the concrete floor with bedding the same as the other animals for two weeks their legs had swollen to the condition as shown in the pictures. Animal A did not receive Vitamin D while animal C received 24,000 I. U. Vitamin D per day from the time she was brought into the dairy barn. Animal C's legs became so bad it was necessary to leave her outside and bring her in only during milking time. This continued for two months after which the swelling started to subside. Nevertheless, she continued to be abnormal and stiff in her gait for seven to eight months and never completely recovered until she was fed cobalt sulfate. The swelling in animal A's legs subsided after she was in the barn for approximately six weeks. These animals, prior to being brought into the milking herd, received an average of three pounds of grain with silage and bent-grass hay in addition to pasture with free choice salt and bone meal available. Three other heifers brought into the barn at the same time showed the same symptoms but not quite so severe. Animal C was three years old at calving time due to inability to settle her earlier.



Animal A

Animal B



Animal C

Figure 5. Comparison of normal and abnormal leg joints.

At the time, we were not aware that this swollen leg condition could be related to copper metabolism so no treatment was tried.

In December 1952, the Oregon Dairy Breeders Association purchased a young Guernsey bull from northwestern Washington. On arrival, it was noted that the bull's front legs were affected by swelling, stiffness, and a buckling at the knees, which hindered his movement. This condition persisted for approximately six months with Vitamin D supplementation. Starting in May 1952, weekly doses of four and one-half grams copper sulfate and 374 mg cobalt sulfate were administered as a drench. In six weeks this animal lost his stiffness and was able to move about normally. The swelling in the joints did not subside but continued to be less evident as the animal proportionately grew. At the end of three months the dark areas on the animal had changed from a light fawn to a dark in spite of the summer sunshine period.

In February 1953, a two year old, of a group of control animals not receiving copper supplementation had a swollen left rear hock. This was accompanied by general uneasiness in the front legs but with no swelling in this region. The animal constantly shifted her weight from one front foot to the other. Copper deficiency symptoms were evidenced by the long hair coat. Treatment consisted of a single nine gram dose of copper sulfate and 750 mg cobalt sulfate. The swelling was reduced to practically normal in one and one-half weeks. It is too soon to determine if the condition will recur.

Condition of Dairy Heifers

In comparing the winter feeding of the 1949-1950 heifers with the 1951-1952 heifers, two things should be noted in their management. The 1949-1950 group of ten heifers had a 14.5 percent crude protein grain ration as compared to a crude protein content of 9.3 percent in a mixed barley and wheat ration fed to the 1951-1952 group of nine heifers. The 1949-1950 heifers received supplemental steamed bone meal and iodized salt in their ration in addition to free choice bone meal and iodized salt. The 1951-1952 group of heifers had no added bone meal or salt in the concentrate ration and this was provided free choice in the form of commercial trace mineral blocks, steamed bone meal and iodized salt.

Both groups of heifers were fed and handled under the same general housing conditions. The animals in each group were pasture bred. An average of three pounds of grain was allowed each animal with grass silage and bentgrass hay provided free choice in unlimited quantities during both periods. The 1951-1952 animals received silage from sample H13994, Table IX, which had a copper content of 17.8 ppm. No analyses was made on the silage for the 1949-1950 group of heifers. Hay analyses is only available for the 1949-1950 group and it was from sample number H10384 with a copper content of 4.6 ppm and molybdenum of 2.1 ppm.

No scouring was noted among the animals of either group at any time. Except for two animals in the 1949-1950 group no breeding difficulty was experienced. One animal in this group gradually declined, and they showed little appetite for grain. One animal had to be removed and placed on a ration of calf manna and alfalfa hay for six weeks to prevent her from dying. Many of these animals preferred the poor quality low protein hay in lieu of the other feed offered. This group consumed a small quantity of salt but practically no bone meal was eaten. It is estimated that approximately five pounds of bone meal was consumed by the ten head in six months. Licking of other animals was observed at times and some "tongue-lolling". See Figure 8 (A).

The 1951-1952 animals were thrifty, maintained good condition, had good appetites and consumed their grain and silage with relish. These animals shed out early in the spring as normal animals should. Bone meal was readily consumed and one hundred pounds of commercial trace mineral blocks were consumed. Free choice iodized salt was available and consumption was normal.

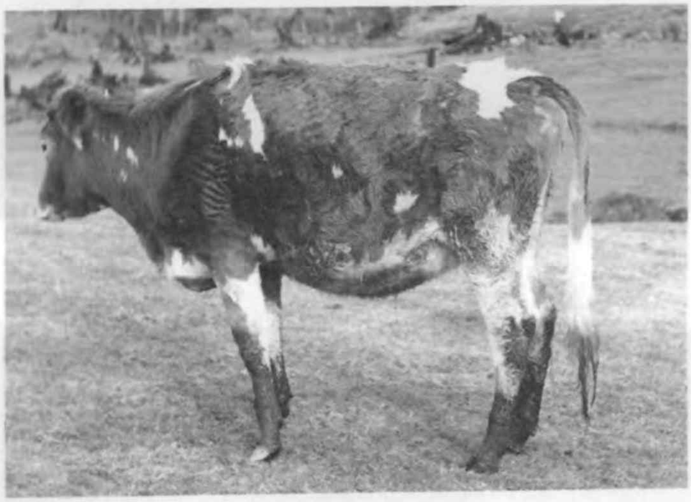
Figure 6 is a comparison between calves showing the difference in general condition of the animals. These pictures were taken during different years, that of the emaciated animal on March 23, 1950, while the thrifty appearing animal's picture was taken May 8, 1952. There is an age difference in these animals; the emaciated animal is approximately 17 months old while the other animal is 27 months old. The 17 month animal died in the fall as previously mentioned.

Figure 7 shows two heifers, A and B, within three months of being the same age at the time the pictures were made. These pictures were taken within fifty days of one another during the spring of different years, and the comparison is made to show the general coat condition. The smooth coated animal A had shed during the normal time. The picture was taken May 8, 1952. The rough coated animal B, photographed on March 23, 1950, did not shed out until late May and early June and the hair coat was always rough appearing and showed poor quality. The lower photograph, Figure 7 (C), was taken May 8, 1952, and shows the same animal B at four years and six months with normal spring coat. Other heifers of the 1949-1950 group in the spring of 1950 showed the same coat characteristics and lateness of shedding as animal A in Figure 6, animal B in Figure 7, and animal A in Figure 8.

Animal B, Figure 8, photographed on May 8, 1952, born March 27, 1949 and calved September 1, 1951, has always shown an abnormal listless condition during her lifetime. Without a background and history, this animal would be judged as normal if the picture was used as the only criteria. At the time of service her vertebral column was apparently permanently injured for she has carried the "roached" back from time of service. Her daily milk production has never gone over 26 pounds for any day and will average 20 pounds per day for six months of her lactation. She has never shown a relish for her feed. When fed eight pounds of grain per day in addition to silage, she will eat approximately half of the grain and silage, toss the rest out of the manger, and leave it. She has done this from the time she has been in the milking herd. When drenched with one pound

Figure 6. Condition of 1949-1950 dairy heifers as compared to 1951-1952 dairy heifers.

Animal A

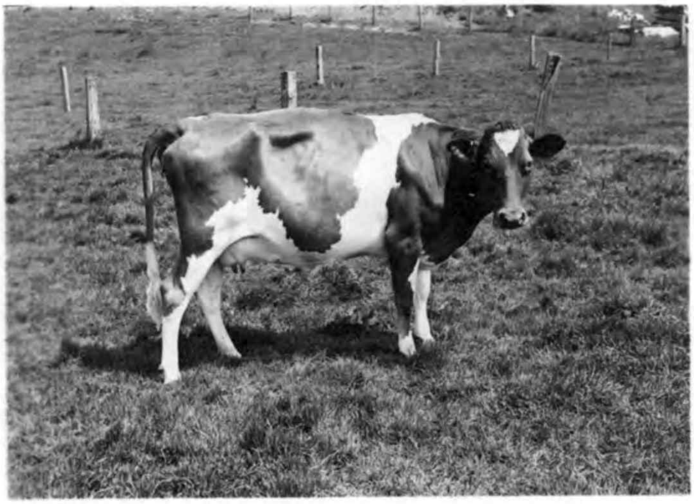


Animal B

Animal C

Figure 7. Comparative shedding and condition of dairy animals.

Animal A



Animal B

Figure 8. Abnormalities in dairy animals.

of epsom salts her appetite improved for approximately one and one-half weeks. When fed sodium acetate at the rate of one-fourth pound per day her appetite was better while receiving the acetate. When the acetate feeding was stopped she again went back to her old practice of poor appetite. This animal has been observed to stand and lick the brass petcock for the milking machine for long periods. She has never been fed cobalt or copper at any time. She has attained her present flesh and condition very slowly over a seven months' period. This animal without question would have benefited materially by copper and cobalt supplementation, but was not fed due to the fact that a similar animal was not available for control purposes.

Condition of Beef Animals

In the early spring of 1950, eighteen beef animals being fed silage and supplemented with bone meal and salt showed an unthrifty condition and many were scouring, particularly the younger animals which had either calved or were nearing calving time. Fecal samples were collected and forwarded for examination which revealed that many of these animals carried a heavy worm population. They were corralled and treated with phenothiazene at the rate of one ounce per 1,000 pound animal. A number of these animals showed some improvement in appetite and the four weakest, with their calves, were isolated and placed on a grain and alfalfa hay ration and given a cobalt drench. Two of these cows and three of their calves died.

The two animals which did not die slowly recovered and were moved to inland pasture some thirty-five miles distant.

The following year, 1950-1951, the beef herd during the winter feeding period was supplemented with a copper, cobalt mineral mixture consisting of the mineral shown under mineral supplement. Approximately four pounds of this mineral were fed daily to some thirty-five head by sprinkling it over their silage. In addition, three pounds of grain per head a day were fed and no trouble was experienced with animals going off feed or scouring except one weaner calf. This calf was wild and would not come to the feed racks, but subsisted on what vegetation could be rustled. After some two and one-half months a heavy snow occurred obliterating all available natural forage and the calf was caught and removed to an isolated building where it was drenched regularly with cobalt sulfate. Within one or two days the animal started eating and it gained 80 pounds in 30 days, an average daily gain of 2.66 pounds per day. Up until this time the animal had shown very little growth with no scouring and the paunch was not developed as compared to the other weaners which were the same age. The rest of the weaners grew and developed normally.

General Unexplained Abnormalities

Complete data is not available for tabulation and summary on reproductive performance due to incompetent and insufficient help during and after the war years. However, cases have been experienced in the milking herd where animals have failed to come into estrus for several months. Other animals have been difficult to settle. There has been difficulty in settling the dairy heifers at times and a number of animals were three years old before having their first calf.

Among other abnormalities noted has been the swelling and soreness of hock joints during certain years. One animal broke out with large abscesses on her thighs for no accountable reason.

Growths under the skin have been observed. These remain permanently and do not seem to be the result of injury. No discomfort has been observed from these growths.

One animal developed redwater a month before calving and died from this cause two weeks before parturition. The calf was apparently healthy and could have been taken by sacrificing the animal.

In certain years there is a great deal of licking among animals particularly in the milking herd after being stanchioned during the winter period for three or four months. The animals lick each other and themselves. When this licking occurs they apparently do not desire common salt as it has been offered. During the increased licking period some animals seem to develop a desire for sucking others and it has been a problem at times. During these abnormal licking periods animals seem to develop a craving for soil, with some animals eating more soil than others. The soil eating seems to be worse during certain years than others.

Livestock men in the County have observed that scouring and unthriftiness in cattle is worse during wet years than dry years.

The pasture is more abundant and luxurious during these wet years than dry years.

SUMMARY

In this study of the value of cobalt and copper supplements for cattle in the Oregon Coastal region it is realized that much of the evidence presented was not the result of carefully controlled experiments from which definite conclusions can be drawn at this time, yet certain trends appear significant. These may be summarized as follows:

1. The similarity of climatic and general soil conditions such as low pH values as compared with areas where known copper and cobalt deficiencies and excesses of molybdenum exist may be considered to be analogous.

2. In most cases, scouring of cattle in the Astoria region may be arrested when copper and cobalt compounds are administered. This indicates, conclusively, that there is a deficiency or improper mineral balance of some nature.

3. The incidence of acetonemia, animals going off feed, and the recovery of these animals where cobalt and copper compounds have been administered indicates that there may be some beneficial effect of this treatment.

4. Improvement in milk and butterfat production with copper, cobalt supplements appears significant. This needs further attention and study.

5. Analyses of forages in other known deficiency areas are similar. Cobalt deficiencies are found in other areas when values drop below 0.07 ppm for extended periods. Complicated copper deficiencies occur when copper values below 10-11 ppm are accompanied

by molybdenum values up to 3.5 ppm. The Astoria area has revealed a mean cobalt value of 0.02 ppm under certain conditions. The analyses for all copper and molybdenum values to date reveal means of 7.0 ppm and 3.5 ppm, respectively.

6. The unthriftiness in dairy heifers during certain years as compared to the thriftiness of other years and symptoms such as swollen legs in dairy heifers, reproductive disorders, depigmentation of the hair coat, late shedding, licking and eating of soil, tend to support the fact that there is some condition present which needs further study by controlled methods.

7. Due to the limited data available and the lack of experimental controls as presented at this time, definite conclusions may be considered as questionable. Further work is warranted on this problem from the evidence presented at this time.

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