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This study was conducted to delineate the cause or causes of winter deaths in deer and to provide information from which emergency feed could be formulated. Deer were shot at monthly intervals through the winter in Wallowa County, Oregon. Samples from the rumen, liver, mandible, blood and feces were taken to study mineral consumption, tissue levels, storage and excretion. Deer collected the next winter from another area of the county were also sampled for comparative purposes. Deer from two other areas in the state were also sampled and along with the Wallowa County samples, were used to establish standards for deer tissue levels of various minerals.

The minerals studied were P, Ca, Mg, Na, Fe, Cu, Mn, S, K, and Co. Mineral supplies, except Mg, were felt to be adequate. The diets of the Wallowa County deer appeared to be marginal in Mg, especially since winter requirements for Mg are apparently higher than for other seasons. Marginal levels of dietary Mg would be

expected to gradually deplete body stores and cause a lowering of blood Mg. A cold environment will lower levels of Mg and so will starvation. If all three of these occurred at once, it was theorized that a "winter tetany" could occur and result in large scale deaths.

Emergency feeding of deer in the past has not been successful and areas of supplemental feeding usually have higher mortality rates than non-supplemented areas. Another trial was conducted to study the effect of prolonged weight loss, followed by starvation, on the acceptance and reactions of animals offered emergency feeds ad lib. Twelve goats were fed chopped orchard grass hay for 43 days, during which time they lost weight. At the end of this time period, they were starved for five days. After starvation they were offered the following feeds ad lib.: barley pellets, alfalfa pellets, 45:55 concentrate to hay ratio pellets, and chopped alfalfa hay or chopped orchard grass hay. The goats seemed able to adapt to the rations without problems as measured by feed intake, rumen pH, rumen lactic acid levels, body temperature and fecal dry matter. They ate only sparingly at first and then gradually increased intake up to full feed over a five day period.

Blood Mg levels in the goats showed a decline with starvation. The body seemed unable to compensate for this decline by increasing absorption from the intestinal tract or controlling excretion as fecal levels remained similar throughout starvation. The blood levels did not return to normal when the goats were first realimented. It

appeared that the goats went into a negative water balance when they were starved, because urine volume increased and water intake decreased. When an estimate of metabolic water was derived, however, the water balance seemed even.

Tissue Analysis and Winter Feeding of Deer

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TISSUE ANALYSIS AND WINTER FEEDING OF DEER

INTRODUCTION

Mule deer are an important resource in Oregon, for they provide not only meat and trophies but also recreation for many people. They make up 60% of the deer numbers in the state and are found east of the Cascade Mountain Range. The state population of mule deer ranges between 300,000 and 400,000, and last year 156,720 hunters spent an estimated 855,800 man days to kill 88,516 deer in the regular season and in special hunts. This represents an estimated monetary expenditure of 15 million dollars.

Special hunts are required when there are damage complaints or when deer over populate their winter range. In most areas of the state the available winter forage limits the number of deer that can be accommodated in any given area. The preferable management technique in areas of high deer density is to reduce the deer herd numbers in selected areas by harvesting the excess does in the fall when they are in good condition, rather than waiting until winter and letting starvation take its toll in weak and young deer.

When deer numbers are balanced in this way, more young animals will survive the winter to become replacement females and trophy bucks in future years. When starvation is left to balance deer numbers with winter feed, the older animals survive and the young fawns die because the older does can reach higher into browse and trees for feed.

This results in a large herd of does, but not many young bucks to replace the past year's harvest.

In the past, rather than balancing deer numbers with the carrying capacity of the winter range, some states have been persuaded by public pressure to attempt to feed deer in winter. These attempts have usually met with failure and, in some cases, resulted in greater losses when compared to areas where deer were not offered supplemental feed.

There are areas in the country where the feeding of deer in a severe winter for a short period of time would appear advantageous. Wallowa County in northeastern Oregon is one of these. There are usually abundant supplies of natural winter feed, more than the normal deer population can utilize. A larger population of deer could be supported on this winter range, but every two to five years a period of deep snow and cold temperatures precipitates large scale winter losses. It takes several years for the deer herd to recover from these losses, and then another storm decimates their numbers again.

The deer herd is kept below its potential and ideal productivity in several ways as a result of deaths or morbidity during these stress periods. First, the total number of deer is reduced. Second, fawns make up the bulk of the deaths so that a large percentage of a year's production of replacement females and bucks may be lost. Third, the productivity of the does is reduced the next year. They give birth to fewer fawns, and many are born weak and become prey for preditors

or die of other causes.

Wallowa County experienced poor deer wintering conditions in 1955, 1956, 1962 and 1964. Fawns made up 94 percent of the carcasses found in 1956, 73 percent in 1962 and 72 percent in 1964. The carcasses were not grouped according to age in 1955. Table 1 is a compilation of the means for various measures of deer population, composition and death losses. The values are means of five management areas in Wallowa County. They were Chesnimnus, Imnaha, Minum, Sled Springs and Wenaha.

Table 1. Wallowa County Deer Statistics.[a]

	1955[b]	1956	1962[b]	1963	1964[b]	1965
Deer/mile	16.8	12.7	12.6	9.7	10.9	12.9
Carcasses/mile	2.4	0.2	0.5	0.0	1.0	0.0
Fawns/100 does	93	70	84	77	93	70

a - from the respective Oregon State Game Commission Annual Reports
b - denotes a severe winter

It can be seen that deer density dropped the year after a severe winter, except in 1964 where the population presumably had not recovered completely from the loss in 1962. The table also shows that the severe winter years produced or were marked by more carcasses per mile. The other salient fact shown by the table is the effect that a severe winter had on does' productivity the following year. The number of fawns per 100 does dropped off in 1956, 1963 and 1965. This ratio

reflects the number of fawns born and the number that live through the summer and into fall.

If these losses could be reduced by providing an emergency feed to carry the deer through a period of inclement weather, then the herd could increase in size. With more carry-over through the critical winter period, deer numbers at hunting time should be substantially greater.

It was the purpose of this research to determine if deficiencies of certain essential nutrients were contributing to winter death losses of deer, formulate an emergency ration to meet these needs and test the palatability and acceptance of the ration on deer in the local area. It became necessary in the progress of this research to study animals subjected to the stress of starvation under laboratory conditions. Observations made during that phase of the research are also reported, and their importance to the deer in winter is indicated.

REVIEW OF LITERATURE

When deer populations are allowed to exceed the carrying capacity of their winter range, large scale losses are apt to occur. A severe storm, which deposits sufficient snow to cover abundant feed coupled with low temperatures, can also precipitate abnormally high winter losses. Thus, it is not without reason that man has attempted to feed deer in the winter when natural feed supplies are depleted.

Scope of Winter Losses

Winter losses in central Utah were surveyed over a three year period by Robinette and Olsen (1944). The winter mortality averaged 10.7 percent of the herd for one mild and two average winters. Taylor and Hahn (1947) reported losses in Texas ranging from 20 percent to 65 percent of an entire herd grazing an area with inadequate winter feed supplies. Einarsen (1956) reviewed losses in the Murderers Creek Basin in Oregon and found that doe losses ranged from five percent to 32 percent, buck losses ranged from three percent to ten percent, and fawn and yearling losses were from 58 percent to 92 percent. He felt that immature deer made up 60 percent to 80 percent of the winter losses on poor ranges in Oregon.

Robinette and Olsen (1944) reported that 63 percent of Utah's losses were fawns, 28 percent does and nine percent bucks. Taylor

and Hahn (1947) estimated that fawns made up 20 percent to 87 percent of their winter losses. When severe winters have precipitated losses in Wallowa County, fawns have made up a large percentage of the carcasses found. They made up 94 percent of the carcasses in 1956, 73 percent in 1962 and 72 percent in 1964 (Oregon State Game Commission Annual Reports).

Deaths in a deer herd are one obvious way that the productivity is reduced, but the poor feeding conditions in winter have their effect on the next year's fawn crop as well. Verme (1963) fed captive does on a low plane of nutrition during a winter period. The next spring the fawns that were born were lighter than fawns out of does on a normal plane of nutrition. There were fewer fawns and those born had less vigor and thus lower survival rates. The lower survival rate due to a severe winter was also pointed out in Table 1. The number of fawns per 100 does was less in years following severe wintering conditions because fewer fawns were born and fewer fawns survived until the next fall to be counted.

Losses in deer are apparently not limited to the winter deaths or the effects on an unborn fawn crop. De Nio (1938) observed two critical periods in the life of deer. The first period was in winter when feed was covered by snow and the second period occurred in the spring when the feed was high in water content. Harris (1945) felt that the heaviest losses in South Dakota occurred in the spring. Einarsen (1956) also

observed heavy Oregon deer losses in the spring. Some Game Commission people in Wallowa County are of the opinion that spring losses are greatest after a severe winter.

Quality of Natural Winter Feed

With the exception of evergreens, the quality of winter forage available to deer is apt to be low because it is mature and weathered. The quality of winter feed is affected by the loss of leaves, the scattering of seeds, the degree of lignification of plant tissues, and the amount of leaching or weathering that has occurred.

Gordon and Sampson (1939) studied six types of California range plants for their variation in composition and quality. They sampled plants at six stages of maturity: early leaf, pre-flower, full bloom, seed dough stage, seeds cast-mature plants, and herbage dry and weathered. The results of their work are summarized in Table 2.

Einarsen (1946) advocated the use of forage protein content as a measure of plant quality. When the crude protein (CP) content of the feed available to deer in winter reached five percent or lower, a crisis for the animals occurred as this level was below their maintenance needs. The digestibility of protein at this level is close to zero. The CP level in the grasses in Table 2 went below five percent in winter. While the other plant groups decreased in CP levels, they remained above five percent. Other workers have reported similar findings

Table 2. Trends of the Various Constituents in the Plant Groups, from the Early Leaf Stage to Maturity.

Plant Groups	Ash	Calcium	Phosphorous	Potassium	Protein	Fiber
Grasses	Decrease	Decrease	Decrease	Decrease	Decrease	Increase
Grasslike	Decrease	Level varies slightly	Decrease	Level varies slightly	Decrease	Increase
Broad-leafed herbs	Decrease	Level varies slightly	Decrease	Decrease	Decrease	Increase
Deciduous half-shrubs	Decrease	Level varies slightly	Decrease	Decrease	Decrease	Increase
Nondeciduous shrubs	Level varies slightly	Level varies slightly	Level varies slightly	Level varies slightly	Level varies slightly	Level varies slightly
Deciduous trees and shrubs	Increase	Increase	Decrease	Decrease	Decrease	Level varies slightly

From Gordon and Sampson (1939)

relevant to the decrease in protein and the increase in fiber with maturity of the plant (Atwood, 1948; Hagen, 1943; DuToit, Louw and Malan, 1935; McCall, 1932; Dietz, Udall, and Yeager, 1962; Hellmers, 1940).

One can also see in Table 2 that the nondeciduous shrubs are relatively unchanged in their chemical content in the winter as compared to spring. Thus, these plants can provide a much needed balance in the winter rations of deer. Dietz et al. (1958) reported similar findings in work with Colorado herb species. The value of these herbs may be overestimated, however, because in winter when they are grazed, the only portions of the remaining plant are ungrazed stems and branches and these are not of as high a quality as were the leaves.

Research on the mineral composition of plants would lead one to believe that the calcium content remains the same or increases, depending on the plant, and phosphorus levels decrease with winter and maturity (Table 2, Dietz et al., 1958; Dietz, Udall and Yeager, 1962; Du Toit, Louw and Malan, 1935; McCall, 1932). The consequence of this decrease in phosphorus and no change in calcium resulted in an increase in the Ca:P ratio from 5:1 up to 34:1 in various reports. There was a lot of variation between plant species and types, but even in the face of sufficient phosphorus, an imbalanced ratio could result in a phosphorus deficiency for a time in winter.

Other minerals have not been studied extensively, but magnesium levels in grasses were found to remain fairly constant by Du Toit, Louw

and Malan (1935). Potassium levels generally declined in the work reported by Gordon and Sampson (1935) but never below levels required by animals.

Smith, Beeson and Price (1946) studied the mineral and protein composition of two areas in North Carolina. One area harbored deer of low productivity, and the other supported a large population of highly productive deer. The minerals studied were calcium, phosphorus, iron, copper, cobalt and manganese. They found that the area of low productivity produced plants with lower levels of protein, phosphorus, and cobalt. There was an apparent decrease in the levels of phosphorus, iron and copper with maturity in the unproductive area, and a decrease in iron levels in the productive area. The iron and copper levels, while they decreased, never went below requirement levels.

There is a paucity of information on the vitamin status of deer, but Haugen and Hove (1960) studied blood levels of vitamins A and E in Alabama deer. They reported the levels of vitamin E in blood to be lower in wild deer than in captive deer fed rations adequate in vitamin E. They also reported two cases of white muscle disease, one in a fawn and the other a yearling buck. Serum vitamin A levels were found to be similar in wild and captive deer.

The digestibility of the winter diet has been studied by Forbes et al. (1941). Their data showed that the winter diet was of low digestibility and barely able to maintain deer in captivity. Smith (1952)

found that the preference of deer for a browse species was dependent upon the digestibility of the protein in it.

So, in general, it can be said that the winter diet of deer may be low or marginal in protein and phosphorus. If it is not low in phosphorus, an imbalance in the Ca:P ratio could lead to a deficiency (Dietz, 1965). The fiber content of the forage increases and, as it does, the digestibility of the feed decreases as well as the digestible energy content (Short and Remmenga, 1965) at the time when, due to lower temperatures, the deer's requirements are higher. Hill (1956) stated that the salt requirements of deer are less in the winter than in summer by 0.5 pound per month, and that vitamins A and D were sufficient in supply if the animals ate a small amount of green feed. If feeds are dry and weathered, there is a possibility of a vitamin E deficiency. Bissell et al. (1945) saw no reason for emergency feed to contain added vitamins, minerals or large amounts of protein if it had a high TDN value. From the preceding review of the literature, it would seem prudent to supply the animals with added phosphorus, protein, cobalt and vitamin E if the high TDN feed were lacking in these.

Winter Feeding Experiments

Most attempts at emergency feeding of deer have not been successful (Rasmussen, 1939; Carhart, 1943; Doman and Rasmussen, 1944; Gerstell, 1942; Hill, 1956; Longhurst, Leopold and Dasmann,

1952; Hunter and Yeager, 1949). In these seven cases, higher death losses appeared to have occurred as a result of the feeding. Murie (1944) was unsuccessful in his attempt to feed elk because the hay contained spiny awns that lacerated the mouths and throats of the elk causing sore mouth (necrotic stomatitis). Honess (1952) reported that a local resident had been feeding mature wheat hay to deer in winter and that the awns from the seed heads were found embedded in the mouths of the deer. These hard, spiny awns had penetrated the rumen wall and had migrated through the diaphragm as far as the lungs. Needless to say, many deaths resulted. The vast majority of other deer losses in the presence of emergency feed are unexplained. Doman and Rasmussen (1944) concluded that "deaths were not due to lack of food but, rather, improper diets or malnutrition."

Maynard et al. (1935) devised a food block composed of molasses and coarse ground soybeans, which they stored in the woods for later distribution in the winter. These were individually distributed to small groups of deer when the snow was deep. The deer did not initially eat the blocks, but when tree branches were piled over the blocks, the deer would eat the branches and then sample the blocks. Once the blocks had been sampled, they were regularly eaten by the deer. Blocks not so disguised were passed by the deer and left uneaten.

Davenport (1939) held weight losses in winter to less than 30 percent by supplementing winter forage with alfalfa hay, clover hay

or cottonseed meal (CSM). The combination of CSM and alfalfa resulted in weight gains and CSM was found to increase the value of almost all natural feeds for wintering deer. This was a logical effect, for CSM is high in protein. Hagan (1943) fed winter diets low in protein to deer and found that they ate very poorly, lost weight and one of the animals died. A diet low in protein would have a low or negative nitrogen digestibility so that even if sufficient energy were present to meet the animal's needs, the feed would be poorly utilized and the animals would lose weight (Forbes et al., 1941).

Davenport (1939) and Maynard et al. (1935) were probably successful in their feeding attempts because they started feeding prior to marked weight losses and before the deer had gone without food for any period of time. Lack of food for several days could also affect what feeds could be utilized and/or would be accepted by the animal. For example, Weeth, Torell and Cassard (1959) fed ewes several different rations prior to fasting them for six days. After the fast, the ewes offered a high fat diet would not eat and had to be offered another ration. The timing of supplemental feeding could thus be important because of the effects of starvation on the animal and rumen function.

Even prior to starvation, the maturity of the winter feed has altered the rumen microbial population. Pearson (1965) studied the rumen organisms found in deer in Texas. Protozoal numbers decreased from 2.5 million per ml. to 0.3 million per ml. with maturity of feed in

winter. They increased again in the spring. Bacterial numbers decreased from eight billion per ml. to two billion per ml. in January. The effects of starvation on top of this may or may not be additive, for when animals are starved the more mature portions of the last plants eaten remain in the rumen.

Effect of Starvation on the Rumen

When ruminants are deprived of food, the numbers of rumen microorganisms decline. Quin (1943) showed this indirectly by measuring gas production *in vitro* from glucose. He used inoculum from starved sheep and as starvation was prolonged, gas production declined. Warner (1962) and Nesic (1960) starved sheep for four and six days, respectively, and reported that not only did the rumen population decline, but also selected species of protozoa and bacteria disappeared completely. The latter also noted a decline in the ability of the rumen liquor to digest cellulose *in vitro*. Meiske *et al.* (1958) fasted a steer for three days and reported similar findings. Prestarvation levels of *in vitro* cellulose digestibility were reduced 68 percent, 84 percent, 90 percent, and 91 percent in four different trials. With this reduced rumen activity, one would expect lowered levels of VFA, the end products of fermentation. Robertson and Thin (1953) starved lactating cows for five days and found that the rumen VFA levels dropped sharply and required six days of re-feeding to return to normal.

Brown and Shaw (1957) compared the VFA levels in normal and ketotic cows six hours after eating and 18 to 24 hours after eating or, in the case of ketotic animals, when they were off feed. They found that the rumen VFA levels declined from 89 and 120 ml./l. to 51 and 59 ml./l.

The physiological effects of starvation have also been studied. Nesic (1960) reported that rumen contractions were weak and at half their normal rate in sheep starved six days. Aylward and Blackwood (1936) fasted a cow and found that rumination ceased on the third day. It would seem that a feed of low digestibility would tend to maintain rumination for a longer period of time than a highly digestible one because it would remain in the rumen longer. The sheep used by Nesic (1960) may have been fed poor hay prior to the fast. The cow (Aylward and Blackwood, 1936) was fed a hay and grain mixture, resulting in a situation which would tend to support this assumption.

Effect of Starvation on Body Metabolites

The metabolic effects of starvation are summarized in Table 3. These observations are generally in agreement with what one would expect to occur in an animal deprived of food. Starvation would limit the substrate for rumen microorganisms to ferment to VFA, and thus rumen concentrations would decline. Blood glucose levels also declined because propionic acid, a glucogenic VFA, would not be

Table 3. Summary of Effects of Starvation on Blood Levels of Metabolites and Rumen Volatile Fatty Acids in Ruminants.

Reference	Ketone Bodies	BUN	Lipids, Cholesterol	Glucose	iP	Ca	Mg	NaCl	Rumen VFA Levels
SHEEP									
Robertson and Thin (1953)	+1								-
Sampson and Boley (1940)	+			-		NC			
Weeth, Torell and Cassard (1959)	+								
Procos (1962)	NC								
Jackson, Burtis and Goetsch (1966)	NC		+	-					
Saba et al. (1966)	+	NC	+	-					
Annison (1960)	+	+	+	-					
Allcroft and Strand (1933)				-					
Watson (1933)					+				
Meyer, Weir and Smith (1955)								NC	
White, Christian and Williams (1956)	+			-	+	-	-		
Christian and Williams (1960)						-	-		
CATTLE									
Aylward and Blackwood (1936)			NC	NC	+	NC		NC	
Hodgson, Riddell and Hayes (1932)				-					
Brown and Shaw (1957)									-
CATTLE, SHEEP AND/OR GOATS									
Juhasz (1962)		+	+						
Morris and Ray (1939)		+		NC	+	-			
Magee (1932)				+ then -					

1 + = increase, - = decrease, NC = no change

available and also loss of starch from the last meal or from rumen microorganisms would escape fermentation and be digested in the small intestine to glucose. The animal would thus need some other form of energy to meet body needs and would mobilize body fat and protein stores. Serum lipid and cholesterol levels increased (Table 3). Serum blood urea nitrogen (BUN) levels increased because the proteins are degraded to amino acids which are in turn deaminated and the remaining carbon skeleton used for substrate in energy yielding reactions.

The mobilized fats are oxidized to acetate molecules, which are condensed to ketone bodies if they cannot enter the Kreb's cycle. Table 3 shows this increase in serum ketones.

When protein is degraded in the body, iP is released. It is possible that the higher levels of iP would cause a deposition of calcium phosphate at bone sites and, because the dietary supply is reduced, blood Ca levels might fall. It could also be that the high levels of iP prevent the release of Ca from the bone to replace serum Ca lost via the feces or urine. Both cases are speculation to try and explain the decline in serum Ca. The decline in serum Mg concentrations has not been explained.

Effect of Starvation on the Physiology of the Animal

Otsuka and Nakajima (1958) reported that sheep's livers after 34 days of starvation showed fatty degeneration and loss of glycogen. This

would agree with what has been said about the body's response to starvation and is symptomatic of ketosis. The glycogen in the liver has been used up, and the liver is yielding amino acids from its protein component. Ferguson (1954) starved pregnant ewes, previously on a high plane of nutrition, from one to six days. He noted that the percent fat of the liver increased from nine percent up to 20 percent. Ewes kept on a low plane of nutrition for 38 days had livers that increased in fat content up to 26.7 percent. This fat was replacing water and protein in the liver.

The liver is not the only organ supplying amino acids. Hight and Barton (1965) fed ewes on a limited feed regimen, and both the liver and the pancreas lost weight. Kirton and Barton (1958) reported significant decreases in weight of the liver, kidney and heart when sheep were permitted only one or two hours of pasture per day.

There is a limit to how much protein can be depleted before body functions are altered. Masters and Morgan (1962) fed sheep three kilograms of wheat straw per week for eight weeks. Liver function, as measured by clearance of bromosulphthalein, was maintained until the seventh week when clearance was impaired. At the end of eight weeks the liver had maintained its structure, but exhibited centrilobular necrosis and slight vacuolation. Another source of amino acids would be muscle tissue. Suzuki (1965) found that the muscles appeared normal after ten days, but showed early signs of atrophy after sheep were

without food for 20 days.

Starvation Survival Times

The length of time that animals can survive starvation is variable, depending on species, condition, temperature of environment and other stress factors. Klieber (1961) stated that a man survived starvation 30 days and a dog lasted 117 days. He starved rats, and they lived from four to 30 days. Otsuka and Nakajima (1958) starved goats for 34 days without losses, and Suzuki (1965) starved sheep 10, 20, 30 and 46 days without losses. Gerstell (1942) starved a deer in good condition at a temperature from 11 to 58°F. The deer lived 14 days. He also starved wild rabbits and skunks. The rabbits exposed to a 5.8 mph wind and 0°F lived 1.75 days. At 0° and no wind they lasted 2.5 days, and at 40° and no wind they lived 5.75 days. The skunks under the same regimen lived 2.0, 4.0 and 8.0 days, respectively. This illustrates not only the effect of temperature and wind, but also a species difference.

Reactions During Realimentation

The reaction of an animal when food is offered after starvation is another area of concern since emergency rations could not be provided for deer without some delay. Animals have been offered partial, half and full rations after starvation and reactions seem to have been the

same. There have not been any digestive disturbances observed (Magee, 1932; Sampson and Boley, 1940; Meiske et al., 1958; Warner, 1962). Young calves on a milk diet did scour when given full rations or half rations after a four day fast (Blaxter and Woods, 1951). Aylward and Blackwood (1936) fed six pounds of hay first and then grain and straw four hours later to a starved cow. The next three days the animal received 12 pounds of hay per day, and they observed that the animal returned to full feed slowly over a two to three day period. Others have made similar observations (Quin, 1943; White, Christian, and Williams, 1956; Weeth, Torell and Cassard, 1959; Procos, 1962). Coop (1949) made the statement: "When feeding recommenced after three to four days of starvation one difficulty has been to persuade the sheep to eat rapidly. The longer the starvation period the less rapidly did the sheep eat."

The capricious nature of realimentation coincides with the gradual reestablishment of rumen population and function. Warner (1962) found that it required two to three days for the bacterial population to return to normal levels after sheep were four days without food. Meiske et al. (1958) reported that in vitro cellulose digestion did not return to normal until three and sometimes four days after realimentation. According to Quin (1943), normal food consumption was attained in three days, but gas production was below par for ten days. Coop (1949) found that the organisms present 18 hours after realimentation were capable of normal

VFA production *in vitro* with glucose as substrate. This was in spite of the fact that normal feed consumption required several days to return to normal, and the pH of the rumen dropped with refeeding and did not return to normal levels for two days. Juhasz (1962) reported the same finding relevant to pH.

When animals are switched from roughage rations to concentrate rations, digestive upsets usually occur (Church, 1969). It is reasonable to assume that changes from one roughage to another of comparable quality should not result in significant alterations in the animals' digestive processes. Bissell *et al.* (1945) studied the digestibilities of several natural forages as well as alfalfa and alfalfa and oats or barley. He switched freely from one feedstuff to another and found no digestive upsets occurred in the deer he was using as experimental animals.

Application to Deer in Winter

Starvation is thus not a simple process, and events set in motion do not terminate at the time of refeeding. The starved animal is slightly to moderately ketogenic. Rumination has ceased or is infrequent, and the rumen microbial population is reduced in number and ability to ferment feedstuffs. In addition, the animal may have had or developed distinct food preferences that are altered or more exacting because of starvation. To further complicate the problem of refeeding, the reactions are altered by prior diet and treatment. Sampson and Boley (1940)

starved groups of ewes twice. The first time the animals ate well after starvation, but the second time the animals had poor appetites and required a longer period of time to recover weight lost. Prior to the second trial the animals' "physiological well-being was less." This may have been the reason for an apparent species difference reported by Anderson (1949). Elk in fair shape, which had been fed alfalfa and grass hay in past winters on a regular basis and were being fed hay prior to a bad storm, were able to withstand a severe blizzard better than deer. The deer had not received supplemental feed until they were forced out of the snow-covered mountains and foothills and into the lower valleys. When they came out, they were in poor shape and had been on a poor quality diet and reduced food intake for some time. They had never been fed artificially before and were seemingly not helped by the supplemental diets. They did eat some of the diets offered; however, deer losses in the areas where supplemental feeding was practiced were in excess of 30 percent while elk losses were nil.

To further complicate the picture, deer in winter will eat forage or browse that they would normally refuse or eat only sparingly of when other food is present. Pine needles or sagebrush are examples of less preferred food. Sagebrush has been shown to deter appetite and halt rumen movements when fed without an adaptation period (Nagy, Steinhoff and Ward, 1964). Smith, Church and Oldfield (1966) demonstrated that essential oils from sagebrush affected the digestibility of some

feeds (grass hay) and not others (alfalfa hay). Pine needles have been shown to cause abortions in beef cattle (MacDonald, 1952). One could speculate that low fawn production after a severe winter is caused by consumption of pine needles during times of heavy snowfall.

Since rumen contractions are weak or absent and since rumination may have ceased, it could be that the starved animal might not be able to handle feed normally. The rumen microbial population is reduced and may not be of the proper type to digest the food and produce conditions in the rumen that would prevent harmful organisms from becoming established. If this were the case, then deaths could result even after the deer ate a seemingly adequate meal.

EXPERIMENTAL PROCEDURE

This study was conducted in three phases (P-1, P-2, and P-3) as follows: P-1 -- tissue analysis of Wallowa deer through a mild winter; P-2 -- tissue analysis of deer from other parts of the state: Steens Mountain area, Millicoma area, and deer from another section of Wallowa County; P-3 -- experimental starvation of goats and post-starvation reactions and preferences.

Phase - 1 Mineral Determinations

During the winter of 1966 and 1967, 14 deer were shot at approximately monthly intervals starting in December and ending in March. A blood sample was taken by heart puncture, when possible, but usually from the chest cavity as the deer were frequently shot in that area. The following tissues were collected: liver, thyroid, metacarpal, mandible, fecal material and rumen contents. The thyroid was weighed in the field and in the laboratory at Corvallis. The rumen contents were also weighed in the field. Mercuric chloride was mixed into the contents to stop microbial fermentation and samples were then taken from this mixture. The carcass, which consisted of the whole body, hide and head left on, with viscera and one front leg removed, was weighed at the end of the collection day at the Enterprise fish hatchery.

The metacarpal length was recorded. The distal one and one-half inches was cut off and labeled epiphysis (Bone A). The next one and one-half inch section was removed and called the shank (Bone B). The section of the mandible containing the deciduous premolars one, two, and three was excised, the teeth were pulled and the bone labeled Bone M. The three types of bone sections were oven dried at 100°C, extracted with ether for 24 hours in a Soxhlet apparatus, and then ashed in a muffle furnace at 500°C for 15 hours. The ash was put into solution with 0.1 N HCl and made up to 50 or 100 ml. Bones A and B were analyzed for Mg, Na, Ca, and P. Bone M, in addition to these, was analyzed for K.

Whole blood was centrifuged and the serum deproteinated with trichloroacetic acid. The protein free filtrate was analyzed for P. Calcium, Mg, Na, and Fe content was determined in the serum. The blood samples from the first collection were extensively hemolyzed and were not used for the mineral determinations. The serum was also analyzed for BUN (Hycel, Inc., Houston, Texas) and blood amino acid nitrogen (BAAN) by the procedure of Hawk, Oser, and Summerson (1949).

The liver was rinsed off with distilled water, blotted dry and weighed. It was then homogenized in a Waring blender. Samples for further study were taken from this mixture, freeze-dried, ether extracted, placed in platinum crucibles and ashed at 500°C. The ash was put into solution with 0.1 N HCl and analyzed for P, K, Ca, Mg, Na, Fe,

Cu, Co, and Mn.

The rumen contents were centrifuged and the decanted liquid was labeled rumen juice (RJ). The solid portion was washed in cheese cloth with distilled water until the wash water was clear. It was then oven dried, ground and labeled rumen dry matter (RDM). A sample was taken, and its crude protein (Kjeldahl) content determined. Another sample was ashed, put into solution and analyzed for Ca, Mg, P, Na, and K. Sulfur was determined separately on a wet ashed sample. The rumen juice was analyzed for Mn, P, Mg, Ca and Na.

The fecal samples were taken from the rectum, oven dried, ground, ashed in a muffle furnace, put into solution and the levels of Ca, Mg, Na, Fe, P, Mn, and K were determined. Sulfur was determined from another sample.

Phosphorus was determined by the procedure of Roger (1960) and S by the method of Chesnin and Yien (1950). All other minerals were determined using an atomic absorption spectrophotometer. For liver Co, liver solutions were treated with ammonium pyrrolidine dithiocarbamate to precipitate the minerals. This precipitate was resuspended in methyl isobutyl ketone to concentrate Co enough to allow its detection on the atomic absorption instrument.

The statistical analysis involved a least squares analysis of covariance with sex, carcass weight, time shot, bone length, rumen content weight and rumen ash percentage used as covariates for various

tissues and minerals. Age and carcass weight were closely correlated ($r = 0.54$) and, thus, carcass weight rather than age was used as a covariate. The rumen juice values of K were inadvertently omitted from the above analysis, and the means were not adjusted for age or sex. A simple analysis of variance was used to test this variable.

Phase - 2 Mineral Determinations

This phase was conducted to compare the levels of minerals in deer tissues from Wallowa County in P-1 with levels found in two other areas of the state and from a different year and location in Wallowa County. Ten deer were shot and sampled on January 17 and 18, 1968, in the Whiskey Creek area of Wallowa County. Nineteen mule deer were collected from the Steens Mountain area in Harney County in February, March and May, 1968. Eight blacktailed deer from the Millicoma Tree Farm in Coos and Douglas Counties were collected in February and March, 1968.

The tissues examined were: liver, mandible, RDM, RJ, feces and blood. Levels of Fe, Mn, Cu, Na, Ca, Mg and P were determined in liver; Ca, Mg, and P in mandible; crude protein, Ca, Mg, P and Na in RDM; Ca, Mg, P, Na and Mn in RJ; Ca, Mg, P, Na, Fe, and Mn in feces and Ca, Mg, P and Na in blood. These tissues were sampled and processed the same as in P-1, except that the rumen contents were rapidly cooled and frozen to stop microbial action.

The statistical treatment for P-2 data was a single covariate, carcass weight, analysis of variance. The data from P-1 were included in the analysis.

Phase - 3 - Starvation and Refeeding Experiment

Fourteen male, year old Angora goats of similar genetic stock were shorn and offered ad lib. a choppedmature orchard grass hay for 54 days. At the end of this time 12 goats were placed in digestion crates and starved for five days. They were allowed water twice daily and salt free choice. At the end of this period they were allotted to one of five rations: alfalfa pellets, barley pellets, 45:55 concentrate to hay ratio pellets, chopped alfalfa hay or chopped orchard grass hay.

Samples taken from the animals included blood, rumen juice (via stomach tube), feces and urine. Water intake was also measured daily. Feed intake and water consumption were measured during the refeeding period. The animals offered the barley pellets were observed for three additional days. Levels of serum Ca and Mg were determined by atomic absorption methods as was fecal Mg. Rumen VFA analysis was by the procedure of Erwin, Marco and Emery (1961). Rumen lactic acid levels were determined by the method of Pennington and Sutherlin (1956).

RESULTS AND DISCUSSION

The data collected in P-1 and P-2 are of a similar nature, but are discussed separately because they were collected for distinctly different purposes. P-1 was initiated to determine seasonal trends in tissue levels of various minerals while P-2 was conducted to compare levels found in other locations in the state with each other and with the area of principal interest.

Phase - 1

Data tabulated in Table 4 show the distributions by age and sex of the animals shot in P-1. The data are grouped according to the date of shooting. The older female in Time 1 was a yearling, and the one in Time 4 was a pregnant doe. She carried two live embryos and was in the process of reabsorbing seven other smaller fetuses. The time periods are abbreviated as T1, T2, T3 and T4 in the remainder of this thesis.

Table 4. Collection Summary, Phase-1.

Time Period	Fawn wt., Carcass, lbs.	Date	Male, Fawns	Female, Fawns	Female, Older	Total Number	Area Collected From
1	50	12-3-66	1	2	1	4	Lower Minum R.
2	41	1-14-67	1	2	0	3	Camp Creek and Lower Imnaha R.
3	41	2-11-67	1	2	0	3	Minum R.
4	47	3-31-67	2	1	1	4	Minum R., Smith Mt. and Whiskey Cr.

The covariates or adjustment factors for all tissue mineral levels and determinations are shown in Table 5. Rumen juice and RDM variables were originally adjusted for rumen content weight in addition to the other two factors. This did not reduce the variance significantly and could only be used on T2, T3, and T4 means, so rumen content weights were disregarded. Significant F values for the covariates are noted with the unadjusted means in Appendix Table 1.

Table 5. Covariates Used in Phase - 1 Data Analysis.

Tissue	Covariates
Bone A	sex, carcass weight and bone length
Bone B	sex, carcass weight and bone length
Bone M	sex, carcass weight
Liver	sex, carcass weight and liver weight
Thyroid weight	sex, carcass weight
BAAN	sex, carcass weight
BUN	sex, carcass weight
BUNH	sex, carcass weight and hour shot
Blood serum	sex, carcass weight and hour shot
Fecal dry matter	sex
Rumen dry matter	none
RDM - crude protein	hour shot
Rumen juice	sex and hour shot

Results obtained from water, fat and ash determinations for the three bones, liver, thyroid weight, BUN, BAAN, and RDM crude protein are presented in Table 6.

From Table 6 it can be seen that dry matter content of the three bones declined, or conversely, water content increased. This is consistent with the decline in fat content. As the fat is mobilized to meet

Table 6. Dry Matter, Ash and Fat Comparisons, Phase-1.

Units	Time 1	Time 2	Time 3	Time 4	F	s
Bone A						
Dry matter, %	64.95^{ab}	74.31^{b}	72.34^{b}	58.43^{a}	7.25*	3.98
Fat, %	7.15^{ab}	11.37^{b}	11.65^{b}	2.94^{a}	4.57*	2.88
Ash, %	34.82^{b}	39.57^{a}	37.41^{ab}	34.41^{b}	4.73*	1.55
Fat, % of dry bone	11.08^{ab}	15.69^{b}	16.27^{b}	4.21^{a}	5.21*	3.76
Ash, % of dry bone	53.66^{a}	53.06^{a}	51.55^{a}	59.17^{b}	7.81*	1.94
Ash, % of dry bone & fat-free bone	60.29	62.89	61.61	61.84	1.76	1.10
Bone B						
Dry matter, %	85.36^{b}	88.85^{a}	78.74^{ab}	70.83^{a}	10.24*	3.92
Fat, %	15.52^{ab}	17.23^{b}	9.75^{a}	2.13^{a}	14.84*	2.77
Ash, %	47.25	48.13	45.67	46.15	1.25	1.59
Fat, % of dry bone	18.28^{ab}	19.77^{b}	12.10^{a}	2.75^{c}	14.98*	3.14
Ash, % of dry bone	55.35^{ab}	53.93^{b}	58.11^{a}	65.29^{c}	20.17*	1.79
Ash, % of dry bone & fat-free bone	67.69	68.45	66.16	65.92	1.74	0.61
Bone M						
Dry matter, %	77.01^{b}	78.10	72.91^{ab}	67.95^{a}	5.18*	3.22
Fat, %	6.05	3.63	1.78	0.68	4.06	2.17
Ash, %	47.48	49.61	47.77	45.50	1.00	2.21
Fat, % of dry bone	7.79	4.67	2.54	0.86	4.04	2.76
Ash, % of dry bone	61.72	64.34	65.43	66.24	2.85	2.51
Ash, % of dry bone & fat-free bone	66.92	66.60	67.14	67.66	0.44	0.99
Liver						
Dry matter, %	30.84	31.50	30.92	29.89	0.35	1.56
Fat, %	3.36	3.54	3.56	2.48$_{b}$	1.27	0.64
Ash, %	1.66^{a}	1.57^{a}	1.68^{a}	1.27	5.01*	0.08
Fat, % of dry liver	10.87	11.31	11.54	8.49	0.68	2.45
Ash, % of dry liver	4.95^{a}	5.31^{ab}	5.73^{c}	5.33^{bc}	7.27*	0.20
Ash, % of dry & fat-free liver	5.22^{a}	5.66^{abc}	6.14^{c}	5.52^{ab}	4.90*	0.29
Thyroid weight, gm.	22.83	50.27	41.99	32.31	1.14	17.81
Blood urea nitrogen, mg.%	15.64	34.41	31.61	21.73	1.72	10.42
Blood amino acid nitrogen, mg.%	5.38	20.85	26.22	20.93	1.34	14.13
Rumen dry matter, % crude protein	12.48^{b}	18.64^{a}	14.85^{ab}	20.10^{a}	5.30*	2.90

^{abc} Means not sharing the same superscript are statistically different at the 0.05 level of probability using an LSD test with adjustments for covariates and unequal observation numbers.

* A significant F value at P = 0.05.

body energy needs, it is replaced by water. When the increase in water and the decrease in fat content is compensated for by expressing ash content of the bones on a dry and fat free basis, then there are no differences in ash content of the bones for the four time periods.

The same explanation might also be suitable for the decline in ash concentration of wet livers. Ash content, when expressed on a dry basis, increased with winter. If one examines the weights of the different minerals in the liver in Tables 7 through 15, the data indicate this might be an artifact. None of the weights is significantly altered with time nor are the percentages, except for K, and K is without a trend. It could be that the animals were grazing close to the ground and thus picking up more sand and silica. The silica could have been absorbed and partially trapped by the liver. Van Volkenberg and Nicholson (1943) reported the presence of sand in the rumen of a deer that had died due to an inadequate food supply. Sand made up 50 percent of the fecal matter.

When samples of the liver from the deer in this experiment were ashed, there was a fraction which was insoluble in 1N HCl. This fraction could have been silica, and could have been responsible for the increase in ash weight on a dry basis.

The weight of the thyroid gland under more typical conditions is a fairly good measure of iodine sufficiency. Hyperplasia of the gland occurs when an animal is in an iodine deficient state, but Underwood

(1966) points out that the gland also increases in weight when animals are exposed to cold and are losing weight.

The thyroid gland turned out to be an extremely difficult organ to dissect under the conditions of collection. The weights were highly variable, and some of the animals were shot in the neck so that substantial hemorrhaging occurred in the thyroid area. On some of the animals it was difficult to distinguish the thyroid gland from the parathyroids. It was thus not possible to determine the iodine status of the deer with any sort of accuracy or confidence.

The blood urea nitrogen and blood amino acid nitrogen values, also highly variable, tended to increase with time from T1 to T3, but due to the high variation the increases were not statistically different. Body protein stores should have been mobilized and been contributing amino acid structures for energy metabolism, especially since the fat content of the bones was declining. On the other hand, the levels of fat in the liver are lower than levels in sheep on high and low planes of nutrition and protein (Ferguson, 1954). Terri et al. (1958) reported BUN levels in eight male deer suffering at least partly from malnutrition. The BUN values ranged from 23 to 34 % mg. Values in Table 6 are within this range during T2, T3 and T4. This may be a reflection of weight loss from T1 to T2 and T3 (Table 4).

There was an increase in the crude protein level of RDM with time. This could indicate that the quality of the diet was improving.

Another possibility could be that the higher levels of urea in the blood were transferred across the rumen wall from the blood stream and/or entered the rumen via saliva. The Kjeldahl procedure does not distinguish between urea and protein. Even if it could, the urea upon entering the rumen, is hydrolized to ammonia by urease, an enzyme which is always present due to the microorganisms. These organisms would also be analyzed as dietary protein and would be considered part of the diet if they were not washed free from the RDM in the laboratory.

One of the major reasons for this phase was to try and detect mineral deficiencies by looking for a gradual decline in organ content or dietary level, as measured by RDM or RJ levels. There are certain inherent difficulties in this type of approach. First, the measures of dietary levels of nutrients are inherently variable for several reasons. The time that the RDM has been in the rumen prior to when the animal was shot will alter its content. The longer it has been in the rumen, the smaller will be the particles because of re-mastication and fermentation of the material.

Cheesecloth was used as a sieve, and the RDM was washed in it. Fine particles of forage would thus be washed through the cloth and not counted as part of the diet. If the RDM were not washed, then salivary secretions would contaminate it and bias its content. If the RDM had been in the rumen for any period of time, the more digestible portions would have been digested and absorbed or passed on down the tract.

This would leave that portion of the diet which was least digestible to represent the diet as a whole in the RDM. The RDM of one animal was estimated to have contained at least 20 percent pine needles. These could have all been eaten in one day, or they could have been accumulated over several days. Because they are probably not especially digestible, they could have remained while the other portions of the diet were digested. The same could be said for small branches, thick stems and portions of mature forages. These feeds are usually of lower quality and would thus cause an underestimate of the real diet.

Bissell (1959) sampled an area where deer grazed, and found a 6.9 percent crude protein (CP) level in the forages. The RDM content from deer in the area was 17.6 percent CP. He then fed an alfalfa and grain pellet to three deer that was 15.7 percent CP and reported that the RDM levels were 16.2 percent, 14.7 percent and 21 percent CP. This shows that RDM levels of CP are not always reliable estimators of dietary levels.

Another source of error, salivary secretions, has been mentioned. They should have been removed from the RDM by washing. These secretions, however, are included in the RJ values and are, themselves, of interest.

Fecal levels of minerals could also be difficult to interpet. If a mineral were being secreted into the lumen of the intestine, then its concentration in the feces would be dependent upon fecal volume. If

the animal were short of food, then fecal volume would be low and the mineral being secreted would have a concentration that would appear to increase. The level of an element in the feces is useful information, but should always be viewed in the light of concentration versus total amount.

Tables 7 through 16 contain the adjusted mineral means for the various time periods. The means are grouped according to mineral and include: P, Ca, Mg, Na, K, Mn, Fe, Cu, S and Co. The minerals are discussed separately with pertinent references cited.

Table 7. Adjusted Means and Variance for Phosphorous, Phase 1.

Variable	T1	T2	T3	T4	s
Rumen juice, mg.%	21.1	15.2	19.0	13.9	0.35
Rumen dry matter, %	0.23	0.31	0.39	0.24	0.01
Feces, % of dry matter	0.44[a]	0.61[a]	0.41[a]	0.95[b]	0.11
Blood serum, mg.%	-	7.87	4.97	4.63	0.90
Liver, % of ash	16.4	17.7	14.3	8.3	2.48
Liver, gm.	1.31	1.56	1.39	1.69	0.23
Mandible, % of ash	17.4	16.9	16.5	16.9	0.59
Mandible, % of wet bone	8.2	8.3	7.9	7.7	0.44
Mandible, % of dry bone	10.7	10.7	10.8	11.3	0.43
Mandible, % of dry and fat-free bone	11.6	11.2	11.1	11.4	0.39
Bone A, % of ash	17.0	15.6	15.8	16.3	0.57
Bone A, % of wet bone	5.9	6.2	5.9	5.6	0.30
Bone A, % of dry bone	9.1	8.3	8.1	9.6	0.38
Bone A, % of dry and fat-free bone	10.2	9.8	9.8	10.1	0.41
Bone B, % of ash	15.2	15.2	15.4	15.1	1.13
Bone B, % of wet bone	5.3	6.0	5.7	5.2	0.54
Bone B, % of dry bone	8.2	8.1	7.9	8.9	0.70
Bone B, % of dry and fat-free bone	9.2	9.6	9.5	9.3	0.75

[abc] means not sharing the same superscript are statistically different at the P = 0.05 level of probability using an LSD test with adjustments for covariates and unequal observation numbers.

Phosphorus

One of the most sensitive measures of a P deficiency is a reduction in serum inorganic phosphate (Long et al., 1957). This drop in iP has been shown in young sheep (Ewer, 1951), calves (Wise, Smith and Barnes, 1958) and in cattle (Theiler, Green and DuToit, 1927). Theiler and co-workers reported no subsequent change in the level of blood Ca, Na or K, but Ewer (1951) reported that the Ca level increased. This discrepancy could be due to age differences in the two groups of experimental animals.

The serum iP levels reported in Table 7 were not significantly different, but there was a trend for lower levels in the latter time periods. Serum Ca levels (Table 8) were not statistically different, either.

Garton (1951) sampled fistulated and slaughtered sheep fed a variety of pastures and diets. Rumen fluid levels of P ranged from 29 to 37 mg. % from sheep fed grass hay, 42 to 68 mg. % from sheep grazing ryegrass and clover pasture and from 60 to 81 mg. % from sheep fed grass hay and linseed oil meal. The rumen juice levels from the collected deer (Table 7) are low in relation to the values reported above from sheep. An animal could draw P from body reserves in the bone for a period of time so that if these deer are indeed deficient in P, their physiological needs could be met in this manner. The other requirement

for P would then be that needed by rumen microorganisms to digest cellulose. Anderson, Cheng and Burroughs (1956) reported that maximum in vitro cellulose digestion was obtained at levels above two mg. % P. The rumen fluid levels in Table 7 are above this minimum level.

The levels of P in RDM (Table 7) are higher than levels of P found to support maximum antler production in white-tailed deer (Cowan and Long, 1959). They found that levels of P at and below 0.25 percent were low when Ca levels in the diet were 0.09 percent. When higher levels of Ca were fed, then P levels of 0.25 percent were adequate. Levels of Ca in this study ranged from 0.29 percent to 0.90 percent of RDM which are above the 0.09 percent level mentioned previously.

The fecal levels of P were significantly higher in T4 than at any other time period, an observation which does not correspond with a marginal P deficiency. Perhaps there was a reduced fecal output and thus a concentration of fecal components; another possibility might be that the dietary P was less digestible.

The bone data, both for P and ash content, were variable and inconclusive. Tillman, Brethour and Hansard (1959), fed 10-month-old steers for 47 days on low levels of dietary P, and the analysis of dry fat-free bone for ash, P and Ca showed no differences. Likewise Ca and P levels in the liver, muscle, heart and kidney were not altered, statistically speaking, but the lower level of P (0.14 percent) produced lower tissue levels in most cases. Roberts and St. Omer (1965),

Eckles, Gullickson and Palmer (1932), and Wise, Smith and Barnes (1958) all found that bone ash was reduced when young sheep, cattle, and calves were placed on low P diets. Eckles, Gullickson and Palmer (1932) also reported that total Ca and P was reduced on a wet basis, but not on a percent of bone ash basis. Total ash weight of a bone seemed to be more affected by low P diets than percent ash.

One could conclude from the data assembled in Table 7 that P was not a problem with the deer during this season. While RJ levels are low in P, other data from RDM, blood, feces and bone indicate adequate phosphorus supplies.

Calcium

From Table 8 it can be seen that there was no alteration in the serum levels of Ca or iP in samples from the deer collected. The Ca content of the bone remained similar and in one case, Bone B, actually increased in concentration on a dry basis. The percent ash of Bones A and B on a dry basis was actually higher in T4 than at any other time period. These results are contrary to results from work with domestic ruminants on low Ca diets.

McRoberts, Hill and Dalgarno (1965) reported that the blood Ca levels and bone ash were reduced in growing sheep fed diets low in Ca. Benzie et al. (1956) reported similar findings on pregnant and lactating ewes and, in addition, noted an increase in serum iP. They also found

that the percent ash followed the same trend as weight of ash in selected bones. Nelson and Tillman (1967) found that adult sheep maintained on a low Ca diet for ten weeks showed lowered blood Ca for three weeks, and then the levels increased to normal for the last seven weeks. Plasma iP also increased during the ten weeks.

The RDM levels of Ca (Table 8) were higher than the 0.18 percent felt to be minimal for growing sheep by Underwood (1966). The fecal levels of Ca were not different from one time period to the next. The other measure of dietary Ca supply would be RJ levels.

The RJ levels of Ca in the deer are similar to levels from sheep on a grass and clover pasture (Garton, 1951). He reported RJ levels from sheep on a "Ca free" diet were 0.5 mg. %. The means from Table 8 are certainly above this level. One would have to conclude that Ca was not a problem for the deer and would thus agree with Dietz (1965) that "Ca is not a problem in the West."

Table 8. Adjusted Means and Variance for Calcium, Phase-1.

Variable	T1	T2	T3	T4	s
Rumen juice, mg.%	4.8	10.5	10.5	7.9	0.26
Rumen dry matter, %	0.46[a]	0.71[b]	0.74[b]	0.34[a]	0.01
Feces, % of dry matter	1.2	1.6	1.6	1.2	0.34
Blood serum, mg.%	-	10.3	6.3	8.6	4.08
Liver, % of ash	0.32	0.34	0.29	0.33	0.03
Liver, mg.	25.0	30.3	28.8	30.4	4.66
Mandible, % of ash	36.6	34.8	34.9	36.5	0.70
Mandible, % of wet bone	17.4	17.3	16.6	16.6	0.74
Mandible, % of dry bone	22.6	22.0	22.8	24.5	1.19
Mandible, % of dry and fat-free bone	24.5	23.1	23.5	24.7	0.75
Bone A, % ash	33.7	31.9	34.0	34.0	3.26
Bone A, % of wet bone	11.7	12.7	12.7	11.7	1.39
Bone A, % of dry bone	18.1[ab]	16.9[b]	17.5[ab]	20.1[a]	2.07
Bone A, % of dry and fat-free bone	20.3	20.1	20.9	21.0	2.07
Bone B, % ash	34.5	34.2	37.6	35.3	1.69
Bone B, % of wet bone	16.3	16.4	17.2	16.3	1.02
Bone B, % of dry bone	19.1[bc]	18.4[c]	21.8[ab]	23.1[a]	1.30
Bone B, % of dry and fat-free bone	23.4	23.0	24.9	23.7	1.23

[abc] see Table 7.

Magnesium

Data collected from the deer (Table 9) are difficult to interpret because the means of the T2 group are generally higher than those of the other groups. The fecal concentration of Mg was higher in T4 which could be an indication of unabsorbed Mg made unabsorbable by the presence of aconitic acid which can be high in fresh green grass. The bone Mg contents were generally lower in T4 than T1 or T3, significantly so in the percent Mg of the wet mandible.

In contrast, the Ca:Mg ratios in dry mandibles were 46, 41, 41, and 49 for the respective time periods. These are all within the normal

range. Also, there was no decrease in liver Ca, no decline in blood serum levels or general increase in bone levels of Ca except for Bone B on a dry basis.

Blaxter and Rook (1954) found that a magnesium deficient diet offered to bottle-fed calves led to a depletion in bone Mg stores of as much as 45 to 50 percent. They reported that diarrhea accelerated the losses. In further work, Blaxter, Rook and McDonald (1954) reported no changes in kidney, liver or spleen levels of Mg, but there was a trend toward lower levels of tissue Ca on deficient diets. Blood levels of Mg were low and the level in one calf fell below 0.5 mg. %. As the bone levels of Mg declined, the Ca levels increased so that the Ca:Mg ratio increased. These reactions are in general agreement with work in other species.

The Mg levels of the bones (Table 9) are on the low side of normal, possibly indicating a marginal dietary supply. Christian and Williams (1960) felt that the Mg requirements in windy, wet, and cold weather were higher for unprotected animals than for sheltered ones. Their data also showed a drop in serum Mg levels when animals were deprived of food. The Mg content of RDM from the deer collected would appear to be marginal in T1, T3 and T4, but the RJ levels of Mg are higher than any levels encountered by Carton (1951). He fed sheep hay, pasture, grain mixes and combinations and then sampled their rumens to determine Mg concentration in the fluid. The Mg levels ranged from 2 to 20

mg. %.

If the deer had been deprived of food by a heavy snowfall, blood levels might have dropped. Magnesium could possibly become a metabolic, if not a dietary, problem with these deer in more adverse weather conditions.

Table 9. Adjusted Means and Variance for Magnesium, Phase-1.

Variable	T1	T2	T3	T4	s
Rumen juice, mg.%	20.1[b]	46.7[a]	22.1[b]	26.0[b]	7.37
Rumen dry matter, %	0.04[a]	0.15[b]	0.08[a]	0.08[a]	0.002
Feces, % of dry matter	0.35[a]	0.65[b]	0.31[a]	0.49[ab]	0.11
Blood serum, mg.%	-	2.86	2.58	2.11	1.01
Liver, % of ash	1.2	1.2	1.1	1.2	0.21
Liver, mg.	106	107	110	112	19.34
Mandible, % of ash	0.79	0.84	0.82	0.74	0.04
Mandible, % of wet bone	0.37[a]	0.41[b]	0.39[ab]	0.34[c]	0.01
Mandible, % of dry bone	0.49	0.53	0.54	0.50	0.02
Mandible, % of dry and fat-free bone	0.53	0.56	0.55	0.50	0.03
Bone A, % of ash	0.67	0.75	0.71	0.65	0.07
Bone A, % of wet bone	0.23	0.29	0.27	0.23	0.03
Bone A, % of dry bone	0.36	0.40	0.37	0.39	0.05
Bone A, % of dry and fat-free bone	0.41	0.49	0.44	0.41	0.04
Bone B, % of ash	0.71	0.64	0.65	0.59	0.05
Bone B, % of wet bone	0.25	0.25	0.24	0.20	0.02
Bone B, % of dry bone	0.38	0.34	0.34	0.35	0.04
Bone B, % of dry and fat-free bone	0.43	0.40	0.40	0.37	0.03

[abc] see Table 7.

Sodium

Bailey (1961) found that the rumen Na levels were directly related to the levels of Na in the saliva of cattle, and that K levels in the rumen juice were more closely related to the levels of K in the diet. When Na is depleted in a short period of time by an open parotid fistula,

the Na in saliva decreases and the level of K increases (Denton, 1956).

There was a sharp decline in the Na content of rumen juice (Table 10) from T1 to T3 and then an increase. At the same time there was an increase in K levels to T3 and a slight decrease to T4. There were no other indications of a Na deficiency since blood serum levels were not altered appreciably, and the bone contents were unchanged except for the Na content of the dry Bone A which increased significantly from T3 to T4.

Table 10. Adjusted Means and Variance for Sodium, Phase-1.

Variable	T1	T2	T3	T4	s
Rumen juice, mg.%	252	212	119	141	59.75
Rumen dry matter, %	0.26	0.19	0.24	0.15	0.01
Feces, % of dry matter	0.13	0.16	0.13	0.14	0.05
Blood serum, mg.%	-	291	314	318	22.02
Liver, % of ash	0.44	0.39	0.33	0.37	0.08
Liver, mg.	35.1	35.0	31.6	34.3	7.49
Mandible, % of ash	1.03	0.97	1.03	1.03	0.03
Mandible, % of wet bone	0.48	0.47	0.48	0.46	0.02
Mandible, % of dry bone	0.64	0.62	0.67	0.69	0.04
Mandible, % of dry and fat-free bone	0.69	0.65	0.69	0.70	0.03
Bone A, % of ash	0.84	0.85	0.92	0.93	0.04
Bone A, % of wet bone	0.29	0.34	0.34	0.32	0.02
Bone A, % of dry bone	0.45[b]	0.45[b]	0.47[b]	0.55[a]	0.03
Bone A, % of dry and fat-free bone	0.50	0.54	0.56	0.57	0.03
Bone B, % of ash	0.92	0.93	0.96	0.79	0.13
Bone B, % of wet bone	0.32	0.37	0.36	0.28	0.04
Bone B, % of dry bone	0.50	0.50	0.49	0.47	0.08
Bone B, % of dry and fat-free bone	0.56	0.59	0.59	0.49	0.08

[abc] see Table 7.

Devlin and Roberts (1963) fed sheep three levels of Na and observed no significant differences in serum Na, K or Cl, but lambs receiving the lowest level of Na lost weight during the 30 day period. Aines and Smith (1957) found when Na was added to the rations of salt deficient cows that the serum Na, K and Cl increased. When Cl was added to the diets, K and Na in the serum decreased.

Potassium

Potassium is not likely to be a problem in animals on a forage diet because of the large amount of K present. It was studied here because of its relationship with Na and other ions. Roberts and St. Omer (1965) fed a series of K levels to fattening steers and found that serum K was lowered and Mg, Cl, Ca and P were increased. There was no change reported for serum Na. Rumen pH and K increased as the levels in the diet increased. Pradhan and Hemken (1967) fed lactating dairy cows low levels of K and found reduced levels of K in serum and milk.

Table 11. Adjusted Means and Variance for Potassium, Phase-1.

Variable	T1	T2	T3	T4	s
Rumen juice, ppm	11.0	14.5	20.3	18.5	19.83
Rumen dry matter, %	0.34	0.46	0.96	0.61	0.05
Feces, % of dry matter	1.3	1.3	1.0	1.9	0.34
Liver, % of ash	47.2^{a}	42.7^{b}	37.0^{c}	44.2^{ab}	1.84
Liver, gm.	3.8	3.7	3.5	4.1	0.32
Mandible, % of ash	0.15	0.17	0.12	0.14	0.04
Mandible, % of wet bone	0.07	0.09	0.06	0.06	0.02
Mandible, % of dry bone	0.09	0.11	0.08	0.09	0.03
Mandible, % of dry and fat-free bone	0.10	0.11	0.08	0.09	0.03

^{abc}see Table 7.

The dietary supply of K in the deer sampled seems to have an upward trend in the RDM and RJ. Bone and fecal levels were not altered, nor was the total weight of K in the liver. The percent K in the liver ash declined significantly to T3 and then increased. This is a soft tissue and the K levels might be expected to be lowered if a K deficiency were at hand. Likewise, if a Na deficiency were present, the K levels in soft tissues would also decline as K replaced Na in the body fluids, such as blood, gastric secretions and saliva. This aspect is discussed under Na.

Iron

Matrone et al. (1957) have shown that diets devoid of iron, when fed to dairy calves, will reduce hemoglobin levels and also serum iron. Blaxter, Sharman and McDonald (1957) supplemented calves on an all milk diet with 20 mg. Fe/day, but this was not enough to raise the blood levels of Fe. The supplement increased the levels of iron in the liver, kidney and the spleen. Lawlor, Smith and Beeson (1965) found that dietary levels of iron below 40 ppm produced lambs that grew slowly, but the serum iron levels were not affected.

Underwood and Morgan (1963) have reported a range in plasma iron for cattle from 57 to 270 meq./100 ml., and a range for sheep of 102 to 304. Ewes on the average had higher levels than rams. Blood levels of iron in the T4 group were less than T2 or T3 (Table 12), but

total liver iron actually increased and fecal concentration did not decline; therefore, iron supplies were felt to be adequate.

Table 12. Adjusted Means and Variance for Iron, Phase-1.

Variable	T1	T2	T3	T4	s
Feces, % of dry matter	0.58	1.10	0.67	0.89	0.20
Blood serum, ppm	-	0.82	0.84	0.44	0.20
Liver, % of ash	0.51	0.56	0.66	0.73	0.25
Liver, mg.	39	53	63	71	26

abc See Table 7.

Copper

The total stores of liver Cu as shown in Table 13 appeared to be lower in T3 than in the other groups, but there was a large individual variation which made the apparent differences non-significant. Engel et al. (1964) reported that liver stores of Cu in dairy calves more nearly reflected the dietary supplies than blood concentrations. The level of Cu in the ration had no effect on the Cu content of the kidney, heart, brain, spleen or muscle, nor were there differences in growth or performance. Dent et al. (1956) also found liver levels to be more reliable than blood in Hereford calves. Bennetts et al. (1941) reported that cattle in a low Cu area had liver levels from 1 to 6 ppm on a dry basis.

Livers from cattle in a normal area had a range from 37 to 231 with a mean of 122 ppm. In the case of data collected in this study, the low level (16.03 mg. of liver copper) in period T3 would be about 92 ppm Cu, which is within the range and near the mean of normal cattle. This would indicate that Cu was not a problem in these deer.

Table 13. Adjusted Means and Variance for Copper, Phase-1.

Variables	T1	T2	T3	T4	s
Liver, % of ash	0.066	0.076	0.016	0.053	0.04
Liver, mg.	5.6	6.5	1.6	4.7	0.36

There is an interrelationship between Cu, Mo and sulfate, but the exact levels at which these interrelationships take place have not been worked out for cattle and sheep or deer; consequently, Mo and sulfate levels were not measured. Fecal and RDM S levels (Table 16) were determined, however, and were not significantly affected by sampling period. Goodrich and Tillman (1966) fed two levels of sulfate, 0.1 and 0.4 percent, and found no differences in serum Cu levels. The RDM levels of S (Table 16) were within this range and so should not be affecting Cu metabolism.

Manganese

There is little information in the literature on changes in tissue levels of Mn in animals on deficient diets for relatively short periods of time. Manganese is required by rumen microorganisms to digest

cellulose and levels in RJ (Table 14) are all within the concentration levels reported by Martinez (1969) to support maximum in vitro cellulose digestion.

Rojas, Dyer and Cassatt (1965) reported lower Mn levels in the livers, bones, kidneys, blood and testes of calves born to cows maintained on Mn deficient diets for 12 months. The cows also had lower blood levels of Mn than controls. Bently and Phillips (1951) fed Holstein heifers for several years on two different levels of Mn. The low level heifers gave birth to a greater number of deformed calves. The tissue levels of Mn in the mothers were not statistically different from those on the higher level, but on the average they were lower. Levels of Mn in the ovaries of the low level Mn heifers were lowered.

Table 14. Adjusted Means and Variance for Manganese, Phase-1.

Variable	T1	T2	T3	T4	s
Rumen juice, mg.%	2.25	1.91	2.11	1.17	0.87
Feces, % of dry matter	0.078	0.069	0.075	0.061	0.01
Liver, % of ash	0.090	0.081	0.067	0.077	0.01
Liver, mg.	7.3	7.3	6.5	7.1	1.64

The liver Mn levels in the deer sampled did not decline, neither have there been reports of malformed fawns in the area although predators would most likely destroy any malformed or weak fawns shortly after birth. Considering the time required to produce symptoms of Mn deficiency, it seemed not to be a problem.

Cobalt

There was much variation in the Co data. This could have been due to animal differences or to the analytical technique used to concentrate the Co. The "F" value for liver content of Co was not significant and, if anything, the means seemed to increase with time (Table 15). Keener, Percival and Morrow (1948) supplemented a natural diet which was low in Co and found that Co concentrations increased in the spleen, kidney and liver. The supplemented sheep also gained 2.5 times as much weight. Marston, Lee and McDonald (1948) also found the same effect on liver levels of Co in sheep. Andrews, Hart and Stephenson (1959) reported that Co drenching increased the liver Co levels in sheep on low Co pastures but they also noted that the vitamin B_{12} activity was higher in sheep that were on a forage adequate in Co as compared to the drenched sheep. This points out the fact that if drenching or feeding of Co in salt or feed is practiced, then the liver level of Co may not be a valid index for B_{12} sufficiency. Normally ingested Co should be utilized for B_{12} synthesis in the rumen or gut.

Table 15. Adjusted Means and Variance for Cobalt, Phase-1.

Variable	T1	T2	T3	T4	s
Liver, % of ash x 10^{-4}	1.8	2.3	3.4	3.2	1.00
Liver, mg.	1.23	1.78	3.03	2.72	0.99

Another indication of Co deficiency would be a reduction in feed intake (Steward, 1953), but the weight of rumen contents were 4, 6 and 4 pounds for T2, T3 and T4 time periods, respectively. It would appear that Co was not a problem.

Sulfur

Smith, Galan and Weller (1964) fed lambs three levels of S. There were no differences in the performance of lambs on 0.13 and 0.43 percent S rations. These two levels encompass the range of values found in the RDM from the deer collected (Table 16). Fecal dry matter levels of S did not appear to decline with time. It would appear from this limited amount of information that S was not a problem for the deer.

Table 16. Adjusted Means and Variance for Sulfur, Phase-1.

Variable	T1	T2	T3	T4	s
Rumen, dry matter, %	0.13	0.19	0.33	0.30	0.10
Feces, % of dry matter	0.30	0.37	0.28	0.33	0.07

Phase-2

After completion of the first phase, it was felt that additional animals should be sampled the next year. Samples also became available from two other areas of the state because of fertility studies being carried on by other Game Commission employees. As was apparent from the literature cited in the discussion in P-1, there is a paucity

of information relevant to deer tissue levels of various elements of nutritional concern. The opportunity thus presented itself to provide tissue levels of mineral elements for comparison with P-1 animals and with other areas of the state.

Underwood (1966) has said, "Mild mineral deficiencies or excess are especially difficult to identify because their effects on the animal are frequently indistinguishable from those resulting from semi-starvation or under-feeding, from protein deficiency or from intestinal parasitism." Without standards to go by, the job would be even more difficult. These four area comparisons should provide some standards and also measures of variation for future use with deer populations.

Table 17 presents information relevant to the distribution of sex and age of the animals collected from four areas (A) in the state. The P-1 animals are grouped together into A1.

Table 17. Distribution of Age and Sex, Mean Weights, Species and Locations for Four Areas in Phase-2 Deer.

Area	Species	Location	Number	Male	Female	Fawn	Yearling	Aged	Weight kg.
1	Mule	Wallowa Co., 1967	14	5	9	12	1	1	21.3
2	Mule	Wallowa Co., 1968	10	7	3	9	1	0	21.8
3	Blacktail	Millicoma Tree Farm	8	3	5	1	4	3	29.5
4	Mule	Harney Co.	19	0	19	0	2	17	39.9

The number of observations in each area for the various tissues were variable due to poor blood samples, bullets in the jaw, or liver and other reasons. These observation numbers are presented in Table 18 and were the numbers used to calculate standard errors of means in Duncan's Multiple Range test.

Table 18. Observations Per Area, Phase 2.

	Area 1	Area 2	Area 3	Area 4
Rumen dry matter	14	10	8	18
Rumen juice	14	10	8	18
Feces	14	10	7	18
Liver values, %	14	10	7	18
Liver values, mg.	14	10	5	16
Mandible	13	9	8	18
Serum Ca	9	9	8	18
Serum Mg	14	9	7	18
Serum P	14	9	6	11

Sulfur was not determined in P-2 because the method was found to be quite variable in P-1 and replication within samples was difficult to obtain. Alterations in the procedure did not reduce this variability. The determination of K was also variable due to contamination of the atomic absorption spectrophotometer with oil from the air pump. The analysis of Co was also discontinued because the precipitate was unstable and subject to clumping. This made replication impossible.

The data were analyzed the first time with carcass weight as a covariate because in P-1, of 183 possible F values for covariates, 17 of 25 significant F's were from carcass weight. The means in Table 19 are, however, unadjusted for carcass weight because, as can be seen from Table 17, the A-4 deer were at least 10 kg. larger than any other group. This resulted in very biased means. When there was a difference in concentration of some element between areas, it was quite apparent, even without adjustment for weight. A simple analysis of variance was thus used. The means were tested with Duncan's Multiple Range Test using 40 degrees of freedom for the error term. Correlations between the level of a mineral in the diet and in the tissues and feces were calculated and appear in Appendix Table 2.

No distinct differences showed up in the area comparisons which are not explainable by either age differences between groups or the normal variation in animals grazing areas of sufficient mineral content. There was not enough information collected on some minerals to support a firm conclusion. Magnesium was the only mineral found to be at least suspect and worthy of further study.

In this discussion Underwood (1966) will be cited freely. He has presented a very adequate summary of the effects of mineral deficiency symptoms and lesions occurring in domestic animals.

Table 19. Phase Two-Component Means for Areas, Variance and F Values

	Area 1[1]	Area 2	Area 3	Area 4	Variance	F
RUMEN DRY MATTER, %						
Crude Protein	16.5	14.3	18.3	14.3	18.35	2.09
Ash	9.5	11.0	6.6	9.2	9.93	2.99*
Ca	0.54^{c}	0.59^{bc}	1.38^{a}	0.87^{b}	0.09	14.79*
Mg	0.08^{b}	0.10^{b}	0.18^{a}	0.08^{b}	0.001	22.00*
P	0.28^{b}	3.31^{a}	0.73^{b}	0.50^{b}	0.25	87.44*
Na	0.21^{b}	0.42^{a}	0.38^{ab}	0.33^{ab}	0.02	4.42*
RUMEN JUICE, mg.%						
Ca	8.1^{ab}	3.3^{b}	5.3^{ab}	9.8^{a}	14.77	7.15*
Mg	27.9^{a}	4.7^{c}	19.8^{ab}	14.8^{b}	61.50	18.00*
P	17.3^{b}	180.9^{a}	192.2^{a}	187.2^{a}	4,648	20.76*
Na	186.1^{b}	96.7^{b}	353.4^{a}	305.4^{a}	10,042	14.13*
Mn	1.83^{b}	0.47^{b}	4.12^{a}	0.76^{b}	1.50	17.11*
FECES, % of dry feces						
Ash	25.8^{a}	11.0^{c}	16.1^{bc}	22.6^{ab}	45.87	10.9*
Ca	1.4	1.6	2.3	2.7	1.34	4.42*
Mg	0.44	0.30	0.59	0.52	0.05	3.00*
P	0.61^{b}	0.55^{b}	1.05^{a}	0.77^{b}	9.50	4.41*
Na	0.14^{ab}	0.04^{b}	0.24^{a}	0.09^{b}	0.007	8.86*
Fe	0.80	0.82	0.35	0.56	0.11	4.04*
Mn	0.07^{b}	0.06^{b}	0.29^{a}	0.05^{b}	0.006	18.83*
MANDIBLE, % dry basis						
Dry matter, %	64.2^{b}	67.6^{a}	68.5^{a}	67.8^{a}	4.18	10.54*
Ash, %	64.2^{b}	67.6^{a}	68.5^{a}	67.8^{a}	4.18	10.54*
Ca	23.0^{b}	24.8^{b}	28.1^{a}	27.6^{a}	3.16	22.48*
Mg	0.51	0.54	0.57	0.52	0.003	2.92*
P	10.9	11.4	12.4	11.2	1.33	3.27*
LIVER, % dry matter						
Dry matter, %	31.0^{a}	29.0^{ab}	28.6^{b}	30.8^{a}	2.65	6.10*
Ash, %	4.21^{b}	4.78^{a}	4.79^{a}	4.76^{a}	0.14	7.50*
Mg x 10^{-2}	5.0^{ab}	4.5^{ab}	5.6^{a}	3.7^{b}	1.50	5.21*
P	0.70^{b}	1.17^{a}	1.26^{a}	0.02^{c}	0.01	427.*
Na x 10^{-1}	1.59^{b}	2.42^{a}	3.04^{a}	2.48^{a}	0.31	12.68*
Fe x 10^{-1}	0.26^{bc}	0.46^{a}	0.39^{ab}	0.20^{c}	0.02	10.31*
Fe, mg.	46.5	68.7	59.2	73.0	929	2.11
Cu x 10^{-3}	2.16	5.69	5.87	3.92	7.42	4.52*
Cu, mg.	3.9^{b}	8.3^{ab}	5.9^{ab}	13.7^{a}	0.35	7.26*
Mn x 10^{-3}	3.30^{a}	2.22^{b}	3.06^{a}	1.55^{c}	0.32	29.69*
Mn, mg.	5.9^{a}	3.3^{b}	4.6^{ab}	5.3^{ab}	0.34	4.53*
BLOOD SERUM, mg.%						
Ca	9.4	9.1	9.0	9.2	1.69	0.17
Mg	2.25^{b}	3.34^{a}	2.70^{ab}	2.99^{a}	0.45	5.64*
P	5.21	7.12	5.75	5.96	2.71	2.48

* significant at 0.05% level

abc Means not sharing the same superscript are statistically different at the 0.05 level of probability using Duncans Multiple Range Test and standard errors of means adjusted for unequal subclass numbers

1
Area-1 Wallowa County, 1967
Area-2 Wallowa County, 1968
Area-3 Millicoma Tree Farm, 1968
Area-4 Harney County, 1968

Calcium

The minimum level of Ca in a ruminant diet for a reasonable level of production is felt to be about 0.27 percent of the dry matter. As can be seen from the RDM level of Ca in Table 19, the Ca levels from all of the areas are above this level. Blood serum levels of Ca are within the normal range for other ruminants. The bone levels of Ca were significantly different in A-1 and A-2 as compared to A-3 and A-4. This is probably an age effect as the animals in the latter group were, except for one deer, all yearlings and older. All of the bone levels of Ca are fully adequate compared to levels reported by Underwood (1966).

Phosphorus

As in the case of Ca, the levels in RDM for P are above levels reported to be necessary to prevent deficiency symptoms, even though there were significant differences between areas. Several of the animals in A-2 were collected from grain stubble fields and could have been eating significant amounts of grain which is higher in P than are forages. Grain was found in the wet rumen contents when they were being washed and dried.

Evans and Davis (1966) fed steers three levels of P: 0.04, 0.16 and 0.54 percent of the dry diet. They reported rumen fluid levels of 20, 42 and 54 mg. percent, respectively, from the three diets. Their

data would indicate that the 17.3 mg. % level in A-1 RJ was low, even though the level in the RDM was seven times higher than 0.04 percent. This discrepancy is probably a result of using RDM, with its inherent limitations, as a measure of dietary quality.

The P levels in the mandible were not different from reported levels in normal calves. Underwood reported bone ash levels of 54.9 percent and P levels of 9.4 percent from P deficient calves. Normal animal levels were, in order, 62.3 percent and 10.7 percent.

The liver is not a storage organ for P and the levels encountered there have no relationship (r -0.04) with levels in other tissues. Most likely, the P levels are related to residual blood in the liver at the time of collection. The most sensitive measure of P adequacy is believed to be the serum level of inorganic phosphate. A normal level would be in the range of 4.5 to 6.5 mg. %. The values reported in Table 9 are all within this range.

Magnesium

Normal blood serum levels of Mg range close to two mg. %. Clinical signs of a Mg deficiency, tetany, begin to appear at blood levels of 1.0 to 1.7 mg. %. The blood levels for the four areas are above this range. These values may be subject to question, however, because it was the author's experience that non-hemolyzed blood samples were extremely difficult to obtain from deer under field conditions. In

the laboratory, the higher serum Mg levels came from the more hemolyzed samples. Several samples were discarded for this reason. It is also possible that body stores were mobilized to maintain blood levels.

The normal bone level of Mg in cows has a range of 0.42 percent to 0.64 percent and that for calves is 0.55 percent to 0.75 percent. The range for deficient calves is from 0.17 to 0.45 percent. This would put the deer in a marginal area between normal and deficient if the species are comparable, or on the low end of normal in the case of A-3 and A-4 because they were older deer.

A dietary level of 0.07 percent Mg is considered adequate to meet nutrient needs, but levels of 0.20 percent are found less likely to produce magnesium tetany than lower levels according to Underwood (1966). Considering the levels found in the RDM, these might also be thought of as marginal. From the discussion in P-1, it was concluded that winter requirements are higher than those of other seasons due to the cold and exposure. There was a correlation ($r = 0.43$) between dietary (RDM) levels of Mg and bone levels, but none with fecal levels. This could mean that higher dietary levels are maintaining higher bone levels of the mineral.

Lush green feed in the spring is low in Mg or at least the Mg is less available than at other times during the year. The winter weather and exposure, which increase Mg requirements, could have forced the deer to utilize body stores of Mg so that reserves are low in the spring.

These conditions could result in lowered blood levels of Mg and grass tetany. The large scale death losses observed by De Nio (1938) in the spring could be explained on this basis.

Sodium

The recommended levels for Na in the diet are at least 0.15 percent. The four levels in RDM are above this figure. A Na deficiency can occur without a change in blood serum levels, but the fecal concentration of Na will decline. There was no correlation between RDM and fecal levels of Na. The Na levels of the liver were determined, but they were not very meaningful as the liver is not a Na storage organ.

Iron

Underwood (1966) says that there is no evidence of the occurrence of Fe deficiency in grazing animals under natural conditions. A heavy parasite load can produce anemia via massive blood losses, but uncomplicated Fe deficiencies are rare.

The levels of Fe in the liver for the four areas differed significantly, but when the actual weight of Fe present in the liver was calculated, then these differences disappeared.

Copper

Liver levels of Cu are good indicators of Cu sufficiency. Normal liver levels (dry weight basis) for sheep and cattle range from 100 to 400 ppm. The levels for horses, pigs and humans range between ten and 50 ppm. This would put the collected deer into the lower range, even though they are ruminants. Cunningham (1949) moved sheep from an adequate Cu area into one deficient in Cu. The beginning liver levels of Cu were 79 ppm. Within the first year they had declined to 7.9 ppm. When a group of these ewes was moved to a Cu fertilized pasture, their liver levels went up to 204 ppm, and lamb ataxia problems ceased. The liver levels of Cu in the collected deer were similar to those levels of the sheep prior to being moved to the deficient pastures, i.e., 21 to 59 ppm.

Manganese

A marginal deficiency of Mn is difficult to determine. Liver levels of Mn are helpful, but not the total answer by any means. The Mn levels of normal animals are from 9 to 11 ppm on a dry basis in the liver. The levels encountered in the deer were above this by about four fold. Levels of Mn in RJ are all within the concentration levels that support normal rumen cellulose digestion *in vitro* (Martinez, 1969). The fecal levels of Mn were not related to liver quantities of Mn ($r = .10$). If the animals

were deficient, one would expect a positive correlation between liver amounts and fecal levels indicative of decreased excretion.

Phase-3

From the accumulated literature on the feeding of deer in winter, it was shown that higher death rates occurred in the areas of feeding compared to non-supplemented areas. The deer being fed had lost a substantial amount of weight and had used up a fair portion of their body fat reserves. They had been on a fairly poor quality diet and/or reduced intake or starvation prior to being fed. During the winter the Game Commission supervisor has examined deer that have died with rumens full of supplemental feed, alfalfa hay. This phase of the work was conducted to study this same situation under laboratory conditions and to study the effect of various feeds when offered ad lib. to animals following a five day fast after having been on a poor plane of nutrition for some time. Yearling Angora goats were used as experimental animals.

The feeds were selected to give a broad coverage of the feeds readily available for use as supplements. They were grass hay pellets, alfalfa pellets, barley pellets, 45:55 concentrate to hay ratio pellets, chopped grass hay and chopped alfalfa hay. The latter two were chopped to facilitate weighing and the pieces were approximately one to 1.5 inches long, as fed.

It was felt that the barley pellets would be most likely to result in severe digestive disturbances, cause the animals to go off feed and scour, and would possibly kill the animals due to high production of lactic acid and/or other toxins produced during rumen indigestion. None of the preceding occurred with any of the rations offered. The goats fed the barley pellets went onto full feed without problems. To be sure that problems would not develop later, these goats were observed for an additional week. They still did not show any signs of complications. Samples from the later time periods (Table 20) were not analyzed extensively because the animals remained in good condition and adapted without any apparent complications.

During the preliminary period, when the goats were fed chopped orchard grass hay ad lib., they lost 8.7 percent of their original weight. During starvation they lost 14.3 percent more, making a total weight loss of 23 percent. During refeeding they gained back a portion of this, 11.9 percent, most of which was probably rumen fill.

Uhart and Carroll (1967) took range-raised steers and fed them alfalfa hay and then suddenly switched them to a 90 percent concentrate ration and allowed ad lib. consumption. Rumen pH and lactic acid levels were measured. The steers ate the high concentrate diet initially, but their rumen pH declined and lactic acid levels increased. The steers went off feed two to three days later when the rumen pH averaged 4.8, and the lactic acid level was 900 mg. percent. The levels of lactic acid

Table 20. Means of Observations During Starvation and Refeeding, Phase-3.

Variable	Prior	S1[1]	S2	S3	S4	S5	R1	R2	R3	R4
Body wt., kg.	26.04	26.13	25.13.	24.40 .	23.77	. 22.86	22.00	22.50	22.83	23.45
Rumen pH	7.00	-	7.51	7.58	7.59	7.40	6.79	6.67	-	-
Rumen lactic acid, mg.%	0.5	0.5	0.2	0.2	0.2	0.2	81.3	66.2	-	-
Fecal dry matter, %	42.3	42.0	47.8	42.9	26.5	23.3	27.2	34.0	38.5	-
Feces, gm.	670	620	276	156	136	121	78	96	156	314
Fecal magnesium, gm.	1.88	1.72	0.62	0.31	0.35	0.31	0.22	0.36	0.91	2.04
Fecal magnesium, %	0.267	0.281	0.228	0.195	0.248	0.253	0.286	0.354	0.601	0.629
Serum magnesium, mg.%	2.48	2.19	2.22	2.01	1.96	1.72	1.93	1.75	-	-
Serum calcium, mg.%	10.9	10.0	10.7	8.6	7.8	8.9	9.2	9.3	-	-
Water intake, ml.	1084	71	160	367	573	415	197	1128	1074	1497
Urine, ml.	587	325	712	887	918	885	763	312	613	792
Daily water balance, ml.	-	-220	-463	-461	-320	-445	-700	+836	+370	+746
Cumulative water balance, ml.	-	-220	-683	-1144	-1464	-1909	-2609	-1773	-1403	-657
Rectal temperature, °F	102	-	102	102	102	102	102	102	-	-
Animals sampled for blood and rumen analysis	All	All	4	4	4	4	10	5	-	-

[1] S = Starvation period
R = Refeeding period

encountered in the goat starvation experiment never approached this level (Table 20). Likewise, the rumen pH never reached the 4.8 level. The limitations of stomach tube samples should be appreciated, but the low lactic acid and normal rumen pH could very well explain why the goats remained on feed.

It is conceivable that because the rumen population of microorganisms was low and because the residual RDM was of a less digestible and more fibrous nature, that Streptococcus bovis, a lactic acid producing organism in the rumen, and/or other similar bacteria had disappeared or were at such reduced numbers that they could not produce enough lactic acid to harm the animal.

It can be seen that fecal dry matter remained normal until the fourth day of starvation (Table 20). It then became moist and covered with mucus. Upon realimentation, the dry matter percentage increased and normal hard pellets were being formed by day two. This would also tend to support the thesis that the goats adapted normally to the new diets after starvation.

The rectal temperatures recorded in Table 20 are another indication that all was well with the goats, for their temperatures were not altered during refeeding. The final evidence of normal adaptation to all of the rations offered is presented in Table 21 and Figure 1. It can be seen from these that feed intake started out low and gradually increased, both on a grams of feed eaten per day and on a calculated digestible

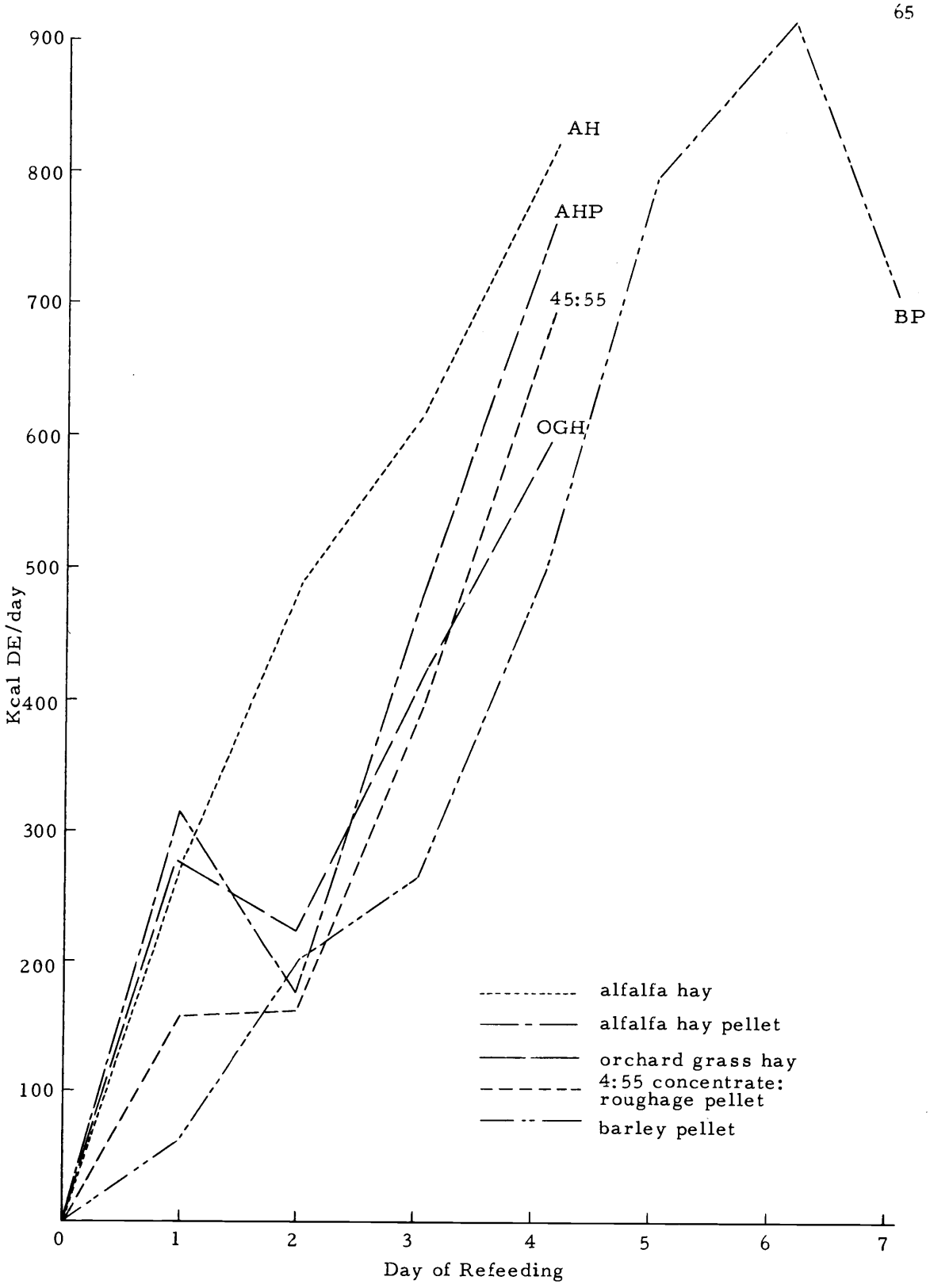

Figure 1. Digestible energy intake

energy basis.

Table 21. Mean Daily Feed Consumption of Five Diets Offered to Goats after Five Days of Starvation, gm. of Feed/Goat/Day.

Diet	Day After Starvation Ended							Number of goats
	1	2	3	4	5	6	7	
Chopped orchard-grass hay, gm.	138	115	208	298				3
Chopped alfalfa hay, gm.	121	220	275	364				3
Alfalfa pellet, gm.	140	77	212	340				2
45:55 pellet, gm.	60	59	143	259				2
Barley pellet, gm.	18	62	84	161	251	284	225	2

It was decided to study the Mg economy of goats during starvation and refeeding because this mineral appeared to be marginal in supply to the deer during the work in P1 and P2. A marginal supply could lower body reserves of Mg so that the animal could not cope with starvation and cold weather, both of which lower blood Mg levels.

The blood levels of Ca and Mg showed a gradual decline during starvation, which is what Christian and Williams (1960) reported. Likewise, the blood Mg had not recovered by the second day of refeeding, while Ca had begun an upward direction. Aylward and Blackwood (1936) studied Ca excretion during starvation and found that the concentration of Ca in the feces did not change, while the amount of Ca lost did decline. Groven (1864), as quoted by Morris and Ray (1939), found food in the intestinal tract after eight days of starvation, so the levels of Mg in the goat feces could be a partial reflection of dietary Mg (Table 20).

The higher levels of fecal Mg in the refeeding period reflect the higher levels of Mg in the ration offered compared to the original diet. The goats apparently were not able to control the amount of Mg they absorbed and/or the amount they excreted even in the face of increased requirements or at least declining blood levels of Mg.

With respect to the water balance of the goats, one can see that (Table 20) water consumption declined and urine volume increased. The moisture in the feces was also considered in calculating the water balance. During starvation the water balance became increasingly negative and was not corrected by the fourth day of refeeding.

Hecker, Budtz-Olsen and Otswald (1964) showed that in sheep deprived of water and food for four days half of the weight lost was water from the rumen. Similar trials with sheep deprived of food, only, gave similar results. If half of the weight lost by the goats was rumen water, then on the average they lost 1.59 kg. of body tissue. If half of this 1.59 kg. was fat, then they would have produced approximately 1,000 ml. of metabolic water from fat oxidation. If all of the 1.59 kg. was fat, then 2,000 ml. of water would have been produced. These two estimates of metabolic water added to the estimated water lost from the rumen, 1,590 ml. would account for 2,590 to 3,590 ml. of fluid. Both of these estimates would put the goats into an even or positive water balance.

Figure 2 demonstrates how quickly the rumen levels of VFA declined. By day two of the fast the production of VFA was at a low point which continued until refeeding, except for iso-valaric acid which increased. Iso-valaric acid can come from degradation of microbial protein, which should increase, for a time, with starvation.

After five days of starvation, the rumen population was able to respond to added feed and produced normal levels of VFA for the animals. This is contrary to the conclusion of Nagy, Vidacs and Ward (1967). They used rumen contents as inoculum, from a deer fed sagebrush pellets. The deer had eaten very few of the pellets and was thus in a semi-starved condition when sampled for inoculum. They reported that the contents from this deer did not work well in in vitro fermentation trials, compared to deer shot in the wild having fed on natural diets. This trial was not a valid experiment to show the effects of starvation, for their own previous work (Nagy, Steinhoff and Ward, 1964) showed that sagebrush, when it made up over 30 percent of the diet, was capable of rendering the rumen and its contents unable to perform normally. In their 1967 work, sagebrush would have made up 100 percent of the diet.

The conclusion from this work with goats would have to be that these animals were able to survive five days of starvation, after a long period of gradual weight loss, and then were capable of realimenting without complications on any of several rations.

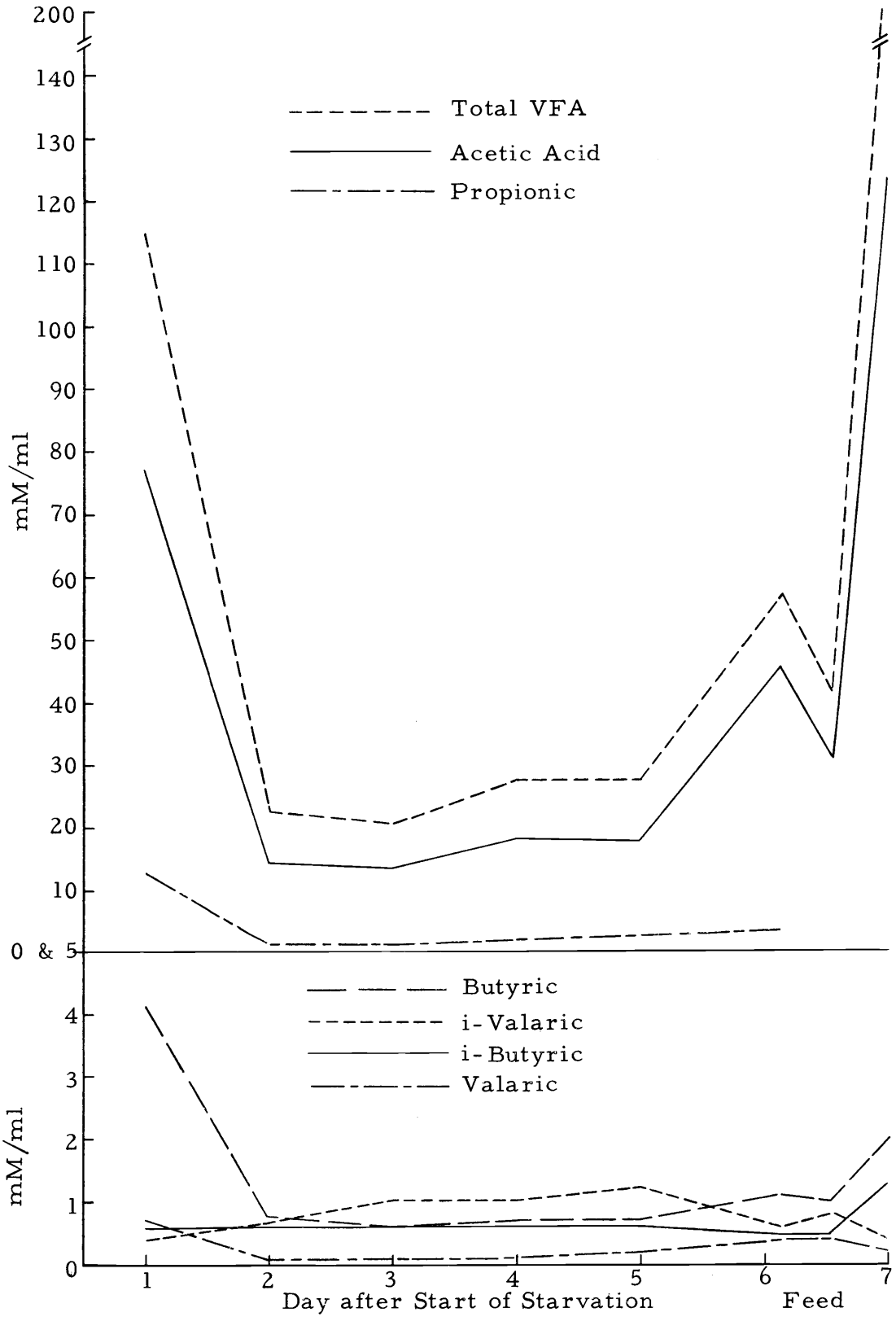

Figure 2. Rumen concentrations of VFA, Phase - 3.

GENERAL DISCUSSION

At the beginning of this work it was felt that the deer should have been able to withstand a short period of cold and limited feed longer than had been reported by the local Game Commission people. Domestic ruminants had been starved for up to 43 days without losses; however, the animals that were starved did not have the added stress of cold temperature.

The second question that occurred was: why did deer losses seem to be higher in areas of supplemental feed as compared to non-supplemented areas? Other ruminants had been starved for fairly long periods of time and had realimented without problems. Unfortunately, papers dealing with realimentation reactions were limited in quantity and scope.

In the past it has been felt that deer died in winter because their body requirements for heat had exceeded what the body was able to provide and due to a prolonged period of limited feed, the animals had used up their readily available heat reserves (glycogen and protein). This situation promoted mobilization of large quantities of fat with the resultant production of ketone bodies. Ketone levels increased in deer in the winter because their protein reserves were low and glycogen stores were exhausted. These are needed to synthesize oxaloacetic acid which combines with acetate units from fatty acid breakdown to form citric

acid in the Kreb's cycle. Without oxalacetic acid, the acetate units are condensed into ketones and when their levels reach a certain point the animal dies of ketosis (Maynard and Loosli, 1962).

This present study with deer tissue levels of Mg and estimated dietary levels of Mg provided suggestive evidence that a "winter tetany" could, under the right conditions, cause deer deaths. Work with humans has shown that hyperthyroid people have lower than normal blood Mg levels (Ito, 1968). The attempts to estimate thyroid activity in this study were inconclusive, but if the deer were combating cold and exposure, then they could have been hyperthyroid for at least a period of time. Sykes, Field and Slee (1969) exposed sheep to 8°C and the blood Mg levels declined 12 percent. The cold temperature did not affect plasma levels of Ca, Na or K. When the sheep were then exposed to an acute cold environment (-20°C, 4 mph wind), blood Mg levels fell lower and Ca declined also. The blood Mg levels did not return to normal, for two weeks, when the sheep were returned to a thermoneutral environment.

Deer in winter are exposed to cold and occasionally feed is limited or lacking. Both of these conditions lower blood Mg levels and could conceivably result in deer deaths. If death did not occur in winter, then body reserves of Mg could be lowered enough to lessen the animals' ability to respond to "grass tetany" in the spring. Field, Suttle and Gunn (1968) reported that blood Mg levels in ewes declined every winter

and that Mg was selectively being removed from bones. They felt that the body supply of Mg was reduced 28 percent between October and November when ewes were without supplement.

No dying animals in the winter or spring were available to sample for body and blood Mg levels. If the "winter tetany" hypothesis or "grass tetany" in the spring were true, one would expect low blood levels of Mg.

A partial answer to the second question was obtained using the goats as experimental animals. After five days of complete starvation, they were able to utilize a variety of rations ranging from all concentrate to high quality hay and low quality hay. Reactions to the feed change were without detrimental effects on the goats. If deer in areas of supplemental feed die due to rumen disfunction, it does not seem likely that deaths are a result of uncomplicated starvation. Long hays were not tested. It might be possible that, in a starved condition, the animals would not be able to regurgitate long hay and compaction could result. The goats, however, did not gorge themselves on the feeds offered after starvation and did not eat enough for compaction to become a problem. It would seem that some other factor is causing death in areas of supplemental feed.

SUMMARY AND CONCLUSIONS

This study was conducted to delineate the cause or causes of winter deaths in deer and to provide information from which emergency winter feed could be formulated. Deer were shot at monthly intervals through the winter in Wallowa County, Oregon. Samples from the rumen, liver, mandible, blood and feces were taken to study mineral consumption, tissue levels, storage and excretion. Deer collected the next winter from another area of the County were also sampled for comparative purposes. Deer from two other areas in the state were also sampled and along with the Wallowa County samples, were used to establish standards for deer tissue levels of various minerals.

The minerals studied were P, Ca, Mg, Na, Fe, Cu, Mn, S, K, and Co. Mineral supplies, except Mg, were felt to be adequate. The diets of the Wallowa County deer were felt to be marginal in Mg, especially since winter requirements for Mg are apparently higher than for other seasons. Marginal levels of dietary Mg would be expected to gradually deplete body stores and cause a lowering of blood Mg. A cold environment will lower levels of Mg and so will starvation. If all three of these occurred at once, it was theorized that a "winter tetany" could occur and result in large scale deaths.

Emergency feeding of deer in the past has not been successful and areas of supplemental feeding usually have higher mortality rates than

non-supplemented areas. Another trial was conducted to study the effect of prolonged weight loss, followed by starvation, on the acceptance and reactions of animals offered emergency feeds ad lib. Twelve goats were fed chopped orchard grass hay for 43 days, during which time they lost weight. At the end of this time period, they were starved for five days. After starvation they were offered the following feeds ad lib: barley, pellets, alfalfa pellets, 45:55 concentrate to hay ratio pellets, and chopped alfalfa hay or chopped orchard grass hay. The goats seemed able to adapt to the rations without problems as measured by feed intake, rumen pH, rumen lactic acid levels, body temperature and fecal dry matter. They ate only sparingly at first and then gradually increased intake up to full feed over a five day period.

Blood Mg levels in the goats showed a decline with starvation. The body seemed unable to compensate for this decline by increasing absorption from the intestinal tract or controlling excretion as fecal levels remained similar throughout starvation. The blood levels did not return to normal when the goats were first realimented. It appeared that the goats went into a negative water balance when they were starved because urine volume increased and water intake decreased. When an estimate of metabolic water was derived, however, the water balance seemed even.

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Appendix I. Unadjusted Means and F Values for Time and Covariates, Phase-1.

Bone A	T1	T2	T3	T4	F time period	F sex	F carcass weight	F bone length
DM*	68.82	70.99	68.56	59.88	7.25*	3.02	3.75	0.64
F PWB*	11.00	9.54	8.74	2.63	4.57*	1.54	0.00	3.07
Ash PWB	35.57	37.78	36.02	36.05	4.73*	6.02*	22.15*	0.27
F PDB*	15.77	13.39	12.67	3.95	5.21*	1.45	0.02	2.60
Ash PDB	51.78	53.24	52.59	60.15	7.81*	0.01	3.42	3.07
Ash PFB*	61.52	61.49	60.21	62.72	1.76	6.94*	14.63*	0.29
P PAS*	16.89	16.00	16.19	15.81	0.34	2.57	1.05	0.00
Percent PWB	6.00	6.05	5.83	5.69	0.49	5.54*	1.65	0.07
Percent PDB	8.74	8.51	8.51	9.51	1.98	1.97	0.01	0.69
Percent PFB	10.39	9.84	9.75	9.91	0.10	4.40	0.01	0.01
Ca PAS	32.79	32.18	34.54	34.91	0.25	0.08	0.05	0.17
Ca PWB	11.67	12.15	12.45	12.37	0.27	0.47	3.96	0.27
Ca PDB	16.97	17.15	18.19	20.65	1.15	0.02	0.58	0.82
Ca PFB	20.17	19.77	20.80	21.53	0.12	0.04	0.83	0.09
Mg PAS	0.64	0.75	0.73	0.66	0.71	0.85	0.18	0.39
Mg PWB	0.23	0.28	0.26	0.24	2.70	0.40	4.38	0.60
Mg PDB	0.33	0.40	0.39	0.40	0.31	0.05	0.67	0.93
Mg PFB	0.40	0.46	0.44	0.42	0.93	0.02	1.04	0.29
Na PAS	0.85	0.86	0.91	0.91	2.07	0.85	2.83	0.85
Na PWB	0.30	0.33	0.33	0.33	1.08	0.69	2.75	0.10
Na PDB	0.44	0.46	0.48	0.54	6.07*	0.57	0.13	0.05
Na PFB	0.52	0.53	0.55	0.57	1.81	0.00	0.08	0.99
Bone B								
DM	85.53	87.38	78.00	72.30	10.24*	4.75*	4.26	0.31
Fat PWB	17.12	15.49	7.91	3.24	14.84*	0.27	2.71	0.17
Ash PWB	46.18	48.06	46.35	46.78	1.25	14.73*	6.58*	3.23
Fat PDB	20.02	17.73	9.98	4.13	14.98*	0.13	3.19	0.13
Ash PDB	53.99	55.00	59.48	64.81	20.17*	0.35	0.75	0.85
Ash PFB	67.51	66.85	66.09	67.66	1.74	10.65*	15.83*	2.33
P PAS	14.91	15.58	15.77	14.79	0.17	0.00	2.76	0.16
P PWB	5.30	5.89	5.68	5.31	3.26	3.20	5.27	0.38
P PDB	7.72	8.30	8.28	8.90	3.37	0.00	0.00	2.60
P PFB	9.17	9.58	9.50	9.26	0.24	0.96	0.00	0.01
Ca PAS	35.04	34.03	37.29	35.12	1.93	0.42	0.03	0.17
Ca PWB	16.17	16.35	17.31	16.44	0.38	6.71*	1.42	0.40
Ca PDB	18.91	18.71	22.18	22.79	6.96*	0.78	0.32	0.04
Mg PAS	0.70	0.65	0.66	0.59	1.69	0.12	0.19	0.02
Mg PWB	0.25	0.25	0.24	0.21	3.94	2.52	3.42	0.12
Mg PDB	0.36	0.35	0.35	0.35	0.31	0.08	0.05	0.47
Mg PFB	0.43	0.40	0.40	0.37	1.25	0.73	0.07	0.00
Na PAS	0.92	0.91	0.94	0.81	0.94	0.28	0.84	0.03
Na PWB	0.33	0.34	0.34	0.30	2.47	1.67	5.63*	0.08
Na PDB	0.48	0.48	0.50	0.49	0.06	0.23	1.36	0.31
Na PFB	0.57	0.56	0.57	0.51	0.84	0.70	1.72	0.01

*DM = Dry Matter, PWB = Percent Wet Bone, PDB = Percent Dry Bone, PFB = Percent Fat Free Bone, PAS = Percent of Ash.

Appendix I. (Cont.)

Bone M	T1	T2	T3	T4	F Time period	F sex	F carcass weight
DM	77.44	77.29	72.17	68.92	5.18	1.17	0.55
Fat PWB	6.00	3.76	1.90	0.49	4.07	0.02	0.04
Ash PWB	47.92	48.79	47.03	46.49	1.00	2.28	1.19
Fat PDB	7.74	4.79	2.65	0.68	4.04	0.01	0.02
Ash PDB	61.89	63.17	65.15	67.46	2.85	0.36	0.13
Ash PFB	67.06	66.35	66.92	67.92	0.44	3.09	0.46
P PAS	17.06	17.57	17.15	15.95	1.11	2.50	13.10
P PWB	8.17	8.57	8.07	7.39	1.48	0.07	2.22
P PDB	10.55	11.08	11.17	10.75	0.92	0.78	8.61
P PFB	11.44	11.66	11.48	10.82	0.90	0.78	11.72
Ca PAS	36.02	36.09	36.06	34.78	3.49	2.30	33.26
Ca PWB	17.25	17.61	16.96	16.13	0.95	0.81	2.30
Ca PDB	22.29	22.80	23.49	23.47	1.55	0.02	3.94
Ca PFB	24.16	23.95	24.13	23.62	1.65	0.02	11.18
Mg PAS	0.79	0.85	0.83	0.73	1.28	0.59	0.63
Mg PWB	0.38	0.41	0.39	0.34	9.17	0.39	0.00
Mg PDB	0.49	0.54	0.54	0.49	2.43	0.33	0.63
Mg PFB	0.53	0.56	0.56	0.49	1.26	0.15	0.53
Na PAS	1.01	1.00	1.06	0.99	1.66	0.35	7.74
Na PWB	0.49	0.49	0.50	0.56	0.47	1.14	1.20
Na PDB	0.63	0.63	0.69	0.67	2.50	0.00	2.50
Na PFB	0.68	0.67	0.71	0.67	1.50	0.01	4.35
K PAS	0.15	0.18	0.12	0.12	0.99	0.26	0.62
K PWB x 100	6.96	8.91	5.87	5.65	1.37	0.52	0.51
K PDB x 100	9.00	11.61	8.15	8.29	0.71	0.29	0.59
K PFB x 100	9.78	12.14	8.36	8.33	0.89	0.34	0.61
Liver							
DM	30.95	31.80	31.08	29.43	0.35	0.03	0.15
Fat PWB	3.34	3.35	3.44	2.73	1.27	0.24	0.08
Ash PWB	1.45	1.55	1.66	1.53	5.01	0.20	0.32
Fat PDB	10.79	10.59	11.10	9.44	0.68	0.19	0.09
Ash PDB	4.67	4.87	5.33	5.20	7.27	0.65	0.06
Ash PFB	5.24	5.45	5.99	5.76	4.90	0.77	0.00
Mg PAS	1.21	1.15	1.08	1.28	0.16	0.67	0.43
Ca PAS	0.33	0.31	0.27	0.35	0.86	0.11	7.83
Na PAS	4.46	3.83	3.23	3.77	0.92	0.24	0.14
K PAS	46.35	43.94	38.09	43.36	14.90	3.64	8.09
Co PAS x 10^{-4}	1.43	2.05	3.19	3.00	2.01	0.57	0.02
Ca PAS x 100	6.67	7.77	1.71	4.98	1.23	0.39	0.01
Fe PAS	0.55	0.50	0.61	0.77	0.57	0.43	0.89
P PAS	16.29	17.78	14.41	18.30	1.49	0.16	0.04
Mn PAS x 100	9.25	7.88	6.53	7.85	0.95	0.39	0.24
Mg MWL*	106.03	94.33	95.69	128.81	0.70	1.90	6.87
Ca MWL	27.50	25.22	24.29	35.13	1.08	0.09	19.26
Na MWL	36.88	31.47	28.38	37.58	0.14	0.00	3.66
K GWL*	3.85	3.52	3.37	4.31	1.12	6.45	6.00

* MWL = Mgs in Wet Liver, GWL = Gms in Wet Liver

Appendix I. (Cont.)

	T1	T2	T3	T4	F time period	F sex	F carcass weight	
Co MWL	12.31	16.26	28.84	29.45	2.43	1.44	0.34	
Ca MWL	57.20	63.96	14.80	47.31	1.06	0.13	0.03	
Fe GWL	0.46	0.41	0.53	0.80	1.02	0.25	3.30	
P GWL	1.35	1.43	1.28	1.82	2.05	1.69	4.80	
Mn MWL	76.80	64.83	57.58	78.23	0.16	0.01	3.66	
Fecal matter								
Mg PFM*	0.34	0.61	0.31	0.50	4.82	2.40		
Ca PFM	1.21	1.57	1.59	1.24	1.24	1.04		
Na PFM	0.13	0.16	0.13	0.15	0.31	0.91		
P PFM	0.44	0.61	0.41	0.95	17.64	0.08		
K PFM	1.26	1.26	1.04	1.92	3.43	0.29		
Mn PFM x 100	7.75	6.93	7.45	6.14	0.82	0.28		
Fe PFM	0.53	1.09	0.66	0.95	4.45	13.20		
S PFM	0.29	0.37	0.28	0.34	0.95	2.63		
								Hour
Blood serum								Shot
Fe PPM		0.82	0.84	0.44	2.57	0.32	1.58	0.53
Ca mg%		9.72	6.60	8.84	0.61	0.66	0.07	0.36
P mg%		7.87	4.97	4.62	9.16	0.17	4.36	11.10**
Na mg%		290.57	314.39	318.38	1.10	1.25	2.73	1.41
Mg mg%		2.86	2.58	2.11	0.32	0.14	0.07	0.18
Blood urea N *	13.92	34.78	33.60	21.68	1.50	2.71	2.89	0.26
Blood urea N - no time	15.64	34.41	31.61	21.73	1.72	4.14	2.97	
Blood amino acid N	5.38	20.85	26.22	20.97	1.34	1.42	5.45	
Thyroid weight	22.83	50.27	41.99	32.31	1.14	1.08	2.16	
Rumen juice								
Mn mg%	2.71	1.36	1.59	1.12	1.11	0.53		3.37
P gm%	20.69	15.19	19.40	13.99	3.14	0.18		0.12
Mg gm%	18.68	46.76	23.33	26.43	8.63	0.52		0.29
Ca gm%	5.69	10.47	9.63	7.64	2.63	1.17		1.07
Na gm%	23.37	21.58	14.03	14.07	2.66	2.07		1.05
Rumen dry matter % of ash							% ash	
Ca	9.88	5.01	8.68	3.45	4.75		4.37	0.10
P	4.14	2.20	4.27	2.41	1.63		1.62	0.02
Mg	0.95	1.06	0.78	0.78	0.38		0.01	0.54
Na	5.78	1.29	2.31	1.51	1.60		0.12	0.30
K	6.91	3.22	10.94	5.96	3.69		1.17	0.06
S	0.14	0.19	0.32	0.30	2.36			0.19
Crude protein % of dry matter	12.50	18.63	14.83	20.10	5.30**			0.00

* N = Nitrogen

** A significant F value at P = 0.05.

Appendix II. Correlation Matrix for Dietary, Fecal and Tissue Levels and Weights of Various Minerals, Phase-2.

	Concentration					
	RDM	RJ	Fecal	Bone	Liver, %	Blood
Magnesium						
RDM		.23	.25	.43*	.38*	.14
RJ	50[1]		.50*	-.04	.20	-.28
Fecal	48	48		.15	.14	.07
Bone	47	47	46		.03	-.03
Liver, %	49	49	48	47		-.03
Blood	47	47	46	45	47	
Phosphorous						
RDM		.20	-.17	.03	.52*	.37
RJ	50		.33	.14	-.51*	.23
Fecal	48	48		.23	-.04	.12
Bone	47	47	46		.21	.32
Liver, %	49	49	48	47		.15
Blood	39	39	38	38	39	
Calcium					Blood	
RDM		.04	.56*	.45*	.01	
RJ	50		.30	.25	-.05	
Fecal	48	48		.48*	.23	
Bone	48	47	46		-.06	
Blood	43	43	42	41		
Sodium				Liver, %		
RDM		-.02	.09	.37*		
RJ	50		.17	.28		
Feces	48	48		-.13		
Liver, %	49	49	48			
Manganese	RJ	Fecal	Liver, %	Liver, mg.		
RJ		.92*	.56*	.26		
Fecal	48		.39*	-.10		
Liver, %	49	48		.51*		
Liver, mg.	44	43	45			
Iron	Fecal	Liver, %	Liver, mg.			
Fecal		-.13	-.15			
Liver, %	48		.66*			
Liver, mg.	43	45				

[1] Numbers to the left of the diagonal are the number of observations used to calculate the correlation coefficient.

* = significant at the P = 0.05 level.