

**"A SURVEY OF COBALT RELATED VITAMIN B₁₂
DEFICIENCY IN COMMON BREEDS OF GOATS IN
SMALL FARMING COMMUNITIES OF THE RIFT
VALLEY OF KENYA."**

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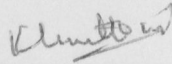


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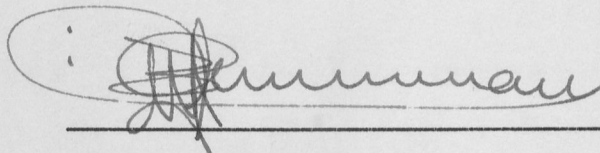
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DEDICATION

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This work is dedicated to my little daughter Muthoni.

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CHAPTER ONE

AND LITERATURE REVIEW

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Abstract

A survey was carried out in order to find out (a) the prevalence of cobalt-related vitamin B₁₂ deficiency in goats, (b) the effect of the deficiency on body condition and reproductive performance and (c) to describe the management practices of the farmers in the area and see how they predispose the goats to Vit. B₁₂ deficiency. The survey was conducted in small farming communities of the endemically cobalt deficient area of the Rift Valley of Kenya.

The survey area was divided into ten clusters each with 80 female goats. Approximately 800 female goats owned by small scale farmers were used in the study for determination of management practices and reproductive performance. Sixteen to twenty female goats in each cluster were used for body condition determinations and blood sampling for the analysis of serum Vit. B₁₂, hematology and blood glucose.

Goats were found to have a wide range of serum Vit. B₁₂ levels, from 20.2 pg/ml to 937.5 pg/ml. The overall mean serum B₁₂ concentration was 205.5 ± 9.37 pg/ml. Only 22 (10.1%) out of 218 goats had serum Vit. B₁₂ levels higher than 370 pg/ml which is considered adequate for sheep. The rest 196 (89.5%) goats had serum Vit. B₁₂ levels less than 370 pg/ml. Of these, 122 (56.4%) had serum Vit. B₁₂ levels less than 180 pg/ml, the deficiency level in sheep while 74 or 33.5% of the goats had Vit. B₁₂ levels in the marginal

deficiency range for sheep, 180-370pg/ml.

The mean serum Vit. B₁₂ levels of the goats which received mineral supplements was 385.9 ± 26.16 pg/ml. This was significantly different ($P < 0.001$) from the mean of 136.2 ± 8.59 pg/ml. for the goats were not given mineral supplements.

Cases of overt anaemia were found in every farm and cluster as demonstrated by RBC counts, Hb concentration, and haematocrit levels which were below the lower limit of the normal range for goats.

Very low reproductive and weaning rates were found throughout the region of study. Cluster mean reproductive rates ranged from 0.6 kids per doe per year to 1.4 kids per doe per year and were far below the expected 2 kids per doe per year. Except one cluster which had comparatively better management, all the other clusters mean reproductive rates were < 1.0 kid per doe per year. The weaning rates ranged from as low as 0.4 to 0.9 weaners per doe per year.

It is concluded that cobalt deficiency is widespread in goats in the study area. The deficiency is characteristically marginal with many goats tending towards the clinical form. The clinical form is demonstrated by the prevalent anaemia, very low reproductive performance, poor body conditions, in some cases severe unthriftiness and a tendency towards low blood glucose levels especially when goats are left to rely on pasture cobalt alone. The incidence of occurrence of cobalt deficiency in the area is reduced by

free grazing and mineral supplementation.

It is recommended that effective control would require very strict management measures. This can be achieved through adequate extension advice particularly to the small scale farmers in the cobalt deficient areas.

Mineral elements form an essential component of animal nutrition. The major, or macronutrient elements are, required by both plants and animals for their maintenance, growth and production (Keen and Graham, 1989). These include: sodium, potassium, magnesium, sulphur, chlorine, copper, calcium and phosphorus. The macro-elements are required in amounts ranging from over 1 to 2 gm/per litre of blood (Underwood, 1977; Church and Pond, 1982).

Trace minerals, or micronutrient, elements are required only in small quantities in the diet ranging from <0.01 to 0.09 gm /litre of blood (Underwood, 1977; Church and Pond, 1982). These include: cobalt, manganese, copper, iron, chromium, selenium, molybdenum, iodine, zinc, arsenic, fluorine, silicon, vanadium, tin, and nickel (Church and Pond, 1982). The macro-elements and some of the trace minerals are classified as essential in animal nutrition because in case of absence or inadequacy in the diet, metabolic dysfunctions and clinical signs of deficiency appear (Cannata et al., 1985; Rice et al., 1987).

Deficiencies of copper, cobalt, iodine, iron, manganese, selenium, and Zinc have been reported to occur in domestic animals and humans under natural conditions. Deficiencies of the other trace elements: tin, vanadium,

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.0 Introduction

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Deficiencies of copper, cobalt, Iodine, iron, manganese, selenium, and Zinc have been reported to occur in domestic animals and humans under natural conditions. Deficiencies of the other trace elements: tin, vanadium,

fluorine, silicon, nickel and arsenic have been reported in experimental animals fed on purified diets but not under natural conditions (Church and Pond, 1982).

Underwood (1977) and Keen and Graham (1989) present descriptions of the many diverse functions of trace minerals as well as specific clinical signs of deficiencies and toxicities. Some of the clinical signs associated with deficiencies of mineral elements include: wasting, skin disorders, non-infectious abortion, diarrhoea, anaemia, loss of appetite, decreased growth rate, low reproductive performance, bone abnormalities, tetany, pica e.t.c. (Underwood, 1981).

One of the most important trace elements in animal nutrition is cobalt (Co). In ruminants, Co is required by the rumen micro-organisms for the synthesis of vitamin B₁₂ (Vit. B₁₂) and Co deficiency is manifested as Vit. B₁₂ deficiency (Church and Pond, 1982). Clinical and subclinical form of this deficiency occur but the subclinical form is most common (Mills, 1981). The severity of Co deficiency varies from a mild state characterized by inapparent clinical signs, to a clinically recognizable state. Clinical Co deficiency state is accompanied by lack of appetite, muscular atrophy, emaciation, anaemia, pica and eventual death (Mills, 1981; Underwood, 1981). The signs are non-specific and often difficult to distinguish from conditions such as energy and protein malnutrition, other mineral deficiencies and chronic helminthiasis (Underwood, 1981).

A number of methods have been applied in the diagnosis of Co deficiency. These include: measurement of cobalt levels in soil and pastures (Mwakatundu, 1977) and in the tissues of animals (Underwood, 1977). Vit. B₁₂ levels in serum has proved a valuable tool in diagnosis because of the ease of obtaining blood samples and also it has been found to be a more direct indicator of dietary Co intake compared to tissue Vit. B₁₂ levels (Findlay, 1972). Faecal Vit. B₁₂ concentration has also been used as an indicator of Vit. B₁₂ deficiency (Jones and Anthony, 1970). Other tests include determination of plasma and urinally levels of methylmalonic acid (MMA) (Gawthorne and Smith, 1974; Millar and Lorentze, 1979) and formiminoglutamate (FIGLU) (Gawthorne, 1968; Russel et al., 1975). Clinical examination together with these diagnostic methods have been used to make conclusive diagnosis (Mgongo et al., 1984; Fisher and Macpherson, 1986; Quirk and Norton, 1987). Among these methods serum Vit. B₁₂ levels has been considered to be the best indicator of Vit. B₁₂ deficiency (Quirk and Norton, 1987).

Most of what is known about Vit. B₁₂ deficiency comes from studies in sheep because sheep are reared in most of the known Co deficient areas. In laboratory studies conducted in goats in Kenya (Mgongo, 1979; Mburu, 1991), it has been shown that goats fed Co deficient hay take more than 23 weeks to develop clinical Vit. B₁₂ deficiency.

1.1 Objectives of the study

Mineral and vitamin requirements of goats have been the least studied area of nutrition in goats (Norton, 1984). In developing countries, goats have been considered to be more suitable than cattle for introduction to poor farmers as a source of milk and meat for home consumption. This is due to the high tolerance to adverse climatic conditions, small size, high fertility, low management needs and the wide acceptance of goat meat. There is a need therefore to know the cobalt requirements of goats which has been reported to be deficient in some areas of East Africa and to provide the essential levels.

Field conditions provide a wider variety of nutritional and management factors than the laboratory, and in view of the rarity of field data on Co deficiency in this species, a survey of Co deficiency was considered in the endemically deficient region of the Rift valley of Kenya.

1.1 Objectives of the study

(i) To report the extent of Co related Vit. B₁₂ deficiency in common breeds of goats kept under different management practices in small holder units in areas of the Rift Valley of Kenya where Co deficiency is endemic.

(ii) To estimate the state of reproductive performance and body condition of the goats in these areas and relate these productivity indicators to the levels of plasma Vit. B₁₂.

(iii) To describe the present farming management practices in the area of study and evaluate the extent that these practices predispose the goats to Vit. B₁₂ deficiency.

1.2.2 Occurrence of cobalt deficiency

Mineral deficiencies is a major constraint to increasing animal productivity in most developing countries. These deficiencies are either marginal or acute. The non-specific signs demonstrated by different workers included inappetance, followed by loss in production and anaemia. Enzootic marasmus is the most appropriate description for Co deficiency based on clinical manifestation (Underwood, 1981).

1.2 Literature Review

1.2.1 Discovery of cobalt deficiency

Cobalt was first shown to be an essential dietary element in sheep in Australia (Underwood and Filmer, 1935; Marston, 1935).

Underwood and Filmer (1935) discovered that Co was the biologically potent element in lamonite which had previously been found to be effective in alleviating "pining" a condition that occurred in sheep in Australia. These workers demonstrated that traces of Co contamination in the lamonite were curative for enzootic marasmus in sheep. Using different fractions of lamonite, they demonstrated the effectiveness of orally administered cobalt in the control of the disease.

1.2.2 Occurrence of cobalt deficiency

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In parts of the world where Co deficiency is prevalent, local names derived from the district or type of country where cobalt deficiency was found are used in reference to the deficiency e.g. moor sickness, bush sickness, mairao dopiness, morton mains disease, Denmark wasting disease, coast disease (southern Australia), coastness, and grand traverse disease. Other names were derived from the clinical picture such as pine (in Scotland), vinqish, daising, enzootic marasmus, neck ail, e.t.c (Robertson, 1971).

Ammerman (1970) has cited some areas of the United States of America with varying degrees of Co deficiency. The deficient areas include portions of New England, lower Atlantic Coastal Plain, northern New York, northern Michigan and parts of the Central Plains.

In many parts of the United Kingdom, cobalt and selenium deficiency are important limitations in livestock production. Cobalt deficiency results in poor growth, loss of appetite and ultimate death (Bremner et al., 1988).

In a study to measure the effects of Co supplementation of pregnant heifers on lactation and calf growth (Quirk and Norton 1982), Co responsive conditions were described in cattle and sheep grazing improved tropical pastures in Queensland.

At Mt. Cotton, South-East of Queensland, Norton and Hales (1976) found a response to Co supplementation in lactating and growing sheep. Ewes supplemented with

cobalt lost less weight during lactation and their lambs showed a higher and more sustained growth than did ewes or lambs from unsupplemented group. When a group weaned lambs were given cobalt, all of them increased liveweight during which time 52% of the unsupplemented control lambs died. Co deficiency was the primary cause of the high mortality rate of the control lambs.

Co deficiency has been reported in Malaysian Kedah-Kelantan cattle grazing a fertirised grass and legume pasture. Injections of Vit. B₁₂ or administration of Co bullets increased body weight and relieved deficiency signs (Manntje et al., 1976). Phosphorous and borderline cobalt deficiency has been reported in Malaysian forages and the provision of mineral supplements resulted in an improvement in the pregnancy rate, percentage calf crop, birth weight, weaning weight and calf growth (Hutagalung et al., 1981).

1.2.3 Occurrence of cobalt deficiency in our region

In southern western Cape province, Co deficiency was considered to be the cause of illthrift and mortality in lambs grazing on mixed dry land pasture consisting mainly of kikuyu grass (Pennisetum clandestinum) (Schneider et al., 1991). Although laboratory assays for pasture Co or serum Vit. B₁₂ were not performed Co supplementation to the ewes and lambs resulted in a marked improvement in growth rate. When a group of the sheep were supplemented with oral Co together with Vit. B₁₂ injections and compared with an unsupplemented control group, it was observed the average body mass per lamb in the treated group was 3.3 kg more

than the unsupplemented controls at the end of the first month. This difference increased to 6.7kg and by the third month, the difference was 14.8 kg. When the initially control lambs were Co supplemented, their body mass raised from 28.8 to 38.7 kg over a period of 40 days since the initiation of supplementation. The dramatic response to Co supplementation suggested that Co deficiency was the primary cause of the illthrift and mortality in lambs.

Robertson (1971) noted that the main loss of production attributable to Co deficiency and difficulty in diagnosis was in the areas where there was only a low grade deficiency. The level of Co in the diet and a positive response to supplemental Co are considered the most reliable confirmatory diagnosis for Co deficiency in many countries.

1.2.3 Occurrence of cobalt deficiency in our region

In East Africa, Co deficiency is referred to as "Nakuritis" and is characterized by a wasting disease in ruminants prevalent in Nakuru area of the Kenyan Rift Valley (Howard (1963). Incidences of Co deficiency are reported mainly along the Rift Valley from Mt. Longonot to Nakuru where the soils are volcanic.

Along the floor of the Rift Valley, the first soil Co analysis was performed by Chamberlain (1957). Out of 31 soil samples analysed, 24 were found to have a Co content

less than 0.08 ppm which indicate a Co deficient or marginally deficient status.

Mwakatundu (1977), studying soil-pasture-plasma mineral relationship in some government research stations in the Co deficient region of East Africa, found that most soils and pastures in Kenya around Nakuru, Molo, Muguga and along the escarpment and in Tanzania around Arusha, Singida, Mbulu and Mpwapwa have cobalt levels as low as 0.04 mg/kg DM. He recorded soil Co levels averaging 0.01 ppm at Iwambi to 1.96 ppm at Mpwapwa. Taking the normal range to be 1 to 50 ppm (Brady 1974), the stations; Baraton, Egerton, Kabete, Molo, Mtwapa, Sang'alo, Iwabi, Malya, Morogoro (dry season), Tanga, Tengeru and West Kilimanjaro were Co deficient. Only Mpwapwa and Morogoro (wet season) had sufficient soil Co contents.

The average pasture Co ranged from 0.027 ppm to 0.058 ppm at West Kilimanjaro (wet season) (Mwakatundu, 1977). At eight stations the Co contents were slightly higher in the wet season than in the dry season. Taking 0.08 ppm Co (Marston 1952) as the minimum requirement of pasture Co for ruminants, the following stations were deficient; -Egerton, Kabete (dry season), Molo, Iwambi, Tengeru (wet season), while the following stations with Co levels >0.08 ppm were adequate; -Baraton, Kabete (wet season), Mtwapa, Sang'alo, Malya, Morogoro, Mpwapwa, Tanga, Tengeru (dry season) and West Kilimanjaro.

1.2.4 Sources of Cobalt in Ruminant Nutrition

Goats fed cobalt deficient pasture from some areas in Naivasha and Nakuru show a decrease in body weight and macrocytic and normochromic anaemia (Mgongo et al., 1984; Gombe and Verjee, 1976; Mburu, 1991). Gombe and Verjee (1976) demonstrated decreased haemoglobin levels, packed cell volume (PCV), and red blood cell (RBC) counts.

A field study on cattle in farms in the endemically deficient Rift Valley region of Kenya compared with farms outside this region showed that plasma Vit. B₁₂ values in poorly managed (Naivasha Co-operative) farm in the cobalt deficient zone were significantly lower than for animals in a farm outside the cobalt deficient zone than for animals well managed in a farm in the cobalt deficient zone (Musewe and Gombe, 1980). The conception rate of cattle in the poorly managed farm was low, (30%) and there was a history of high calf mortality (calves born too weak to survive) and this resulted in an overall lower productivity rate (Musewe and Gombe, 1980). This suggests that management practices could play a role in the occurrence of cobalt deficiency.

The production of cattle grazing forage in a Co deficient area will be limited more by lack of this element than by either that of energy or protein (Mwakatundu, 1977). It has been shown that insufficient Co intake coupled with inadequate energy and protein intakes seriously limit animal production in East Africa (Roeder, 1980).

1.2.4 Sources of Cobalt in Ruminant Nutrition

Ruminants obtain Co from herbage, to a lesser extent from the soil and from commercial feed and mineral supplements (Mills, 1981; Underwood, 1981).

Meat and bone meal, molases, yeast and cereal feeds contain higher levels of Co than pasture and meadow grasses (Underwood, 1981). But these commercial feed supplements are expensive and not easily affordable by the peasant farmers in East Africa. Therefore, pasture cobalt serves as a major source of the micronutrient element to the animals.

1.2.4.1 Factors affecting availability of Cobalt to the Ruminant

Complete absence of Co in the soil is a rare occurrence (Underwood, 1981). Therefore the amount of Co available to the animal is the important factor in the occurrence of the deficiency. Where the Co level in the soil is normal, enough is always available in the grazing and deficiency does not occur. Generally, herbage Co levels below 0.08 ppm on dry matter basis leads to Co deficiency (Underwood, 1981) and a mean soil Co concentration of 0.17 ppm acetic acid extractable Co is regarded as deficient (Russel et al., 1975).

When the levels of cobalt are below normal, several factors determine the degree of Vit. B₁₂ deficiency in ruminants. The concentration of all minerals in crop and forage plants depends on four basic interdependent factors: the genus, species, or strain (variety), the type of soil on which the plant grows, the climatic and seasonal conditions during growth and the stage of maturity of the plants. The soil type, its Co level, pH, and degree of aeration determine Co uptake by plants and therefore the element's availability for the ruminant animals grazing in such pastures (Underwood, 1981).

High levels of Calcium Carbonate in the soil affects availability of Co to the plants. In a review of cobalt deficiency in ruminants (Robertson, 1971) Co deficiency disease was reported in sheep raised in a paddock on a New Zealand property where the soil contained 85% Calcium Carbonate. The carbonate had been washed down from a limestone hill near the paddock. In Hebridean Islands of Scotland a condition called pine which clinically resembles Co deficiency occurs commonly. This condition is associated with areas where the ground is largely shell sand. The high content of Calcium Carbonate interferes with uptake of cobalt by the herbage even when the cobalt is supplied as a top dressing (Robertson 1971).

Availability of cobalt is reduced by increased manganese oxide in the soil and heavy liming (Georgievskii et al., 1981).

The uptake of cobalt from the soil by plants is influenced greatly by soil moisture content. Water logging leads to increased soil cobalt uptake by plants (Underwood, 1981). The cobalt content of a plant growing on poorly aerated water-logged low cobalt soils can greatly exceed that of a plant on a well-aerated, freely drained cobalt rich soil (Mills, 1981). Mwakatundu (1977) reported higher pasture cobalt levels in the wet season than the dry season in these areas of the Kenyan Rift Valley.

In seasons with high rainfall some of the cobalt in the top soil is leached out and the available Co in the herbage is diluted owing to the lush herbage growth (Underwood, 1981). This dilution effect in the lush growth is the cause of Co deficiency in some ruminants on prolific pastures (Scheidner et al., 1991). During the dry seasons, provided there is enough grass for the animals to graze, the cobalt in the soil will be available to the plants and the slower plant growth does not unduly dilute it.

The concentrations of a number of mineral elements including Co decrease in crops and herbage with advancing maturity. The shedding of the seed is usually associated with losses of a large proportion of minerals so that the remaining straw is a poor source (Underwood, 1981). Where mineral nutrients in the herbage are marginal in respect to animal requirements, changes in concentrations brought about by climatic or seasonal influences and by plant maturity and seed shedding are significant factors in

determining the incidence or severity of deficiency states in livestock which wholly or largely depend on those plants for their mineral requirements.

Underwood, (1981) has discussed the importance of soil management practices. Two principal means of modifying the mineral composition of feeds and forages are the application of fertilizers and the use of soil amendments such as lime and sulphur. Application of lime raises the pH of soil and decreases the absorption of Co by herbage since Co absorption is favoured by acid soils (Underwood, 1981). Increasing concentration of sulphur in the soil results in lowered pH and favours Co uptake. Other management factors like irrigation and breeding and selection of higher yielding cultivars, imposed by man in his efforts to increase crop or pasture yields, can sufficiently influence cobalt supply to grazing animals. It is suggested that the selection of grasses and use of suitable fertilizers and grazing management could be used to offset mineral deficiency in livestock (Mills, 1981).

Contamination of herbage with soil and dust provides a significant source of Co to grazing animals. This is important especially when the grazing intensity is high, when the pasture is short and availability is low. In such conditions, soil ingestion by grazing animals provides an important source of Co and iodine whose concentrations are higher in the soil than in the herbage growing on the soil (Underwood, 1981).

Long pasture has been shown to cause Co deficiency in lambs by reducing soil ingestion (Andrews et al., 1958, Mason and Mackay, 1983; Scheidner et al., 1991). When lambs graze on long pastures the chances of ingesting the soil are low and the lambs are therefore predisposed to Co deficiency.

Under grazing conditions goats may avoid mineral deficiencies when given access to browse since they select legumes in preference to grass and legumes are known to be richer in Co than grass (Norton, 1984). Despite this, goats have proved to be just as susceptible to Co or Vit. B₁₂ deficiency as sheep and cattle (Norton and Hales, 1976).

In many parts of the world, the Co deficient and non-deficient areas are reasonably well known and stock are changed to cobalt adequate pastures after grazing for a time on deficient pastures (Marston, 1935). Where top dressing has been carried out in selected areas of a pastures, sheep have been observed to graze the top dressed portions preferentially although no difference in the herbage growth could be found (Robertson, 1971). It is strongly believed that when ruminants are left free to graze on mixed pastures, they are able to select and graze on the Co rich pastures (Marston, 1935; Robertson, 1971).

In a farming system where intercropping is practiced, the type of plants making up the herbage in the boundary areas between different crops are important since some plants take up more cobalt from the soil than others

(Underwood, 1981). Pastures compete for soil Co with the intercropped plants and this reduces the amount of Co available to the pastures. Grasses and cereals are poorer in Co compared to legumes; the cobalt contents of heather, bracken, many common weeds e.g. seaweed are often substantially higher than that of grass species. Underwood, (1981) has emphasized that the cobalt contents of clovers, ryegrass and cocksfoot may differ little when soil cobalt is low, but enhancement of extractable soil cobalt either by increasing soil drainage or by direct application of Co promotes a much greater increase in the cobalt content of clover than of grass species. Cobalt contents of barley grain and straw is low and other protein concentrates of plant origin are rich sources of Co compared to barley grain (Mills, 1981; Underwood, 1981).

When such factors which modify the evidence and distribution of Co deficiency are taken into account, the recognition of regional differences in cobalt status by geochemical and soil survey and analysis has a potential for the identification of high risk areas that do not appear to be adequately recognized by nutritionists and veterinarians.

1.2.5 Metabolism of Cobalt

Co is well absorbed by small laboratory animals and man. The absorption site is the small intestine, mainly the ileum. An association of Co and iron absorption by an active process has been suggested (Underwood, 1977) and there are

indications that its metabolism is closely associated with that of folate. Co is not well absorbed in ruminants (Keen and Graham, 1989). In ruminants Co is used in the synthesis of Vit. B₁₂ and related compounds by rumen microorganisms (Porter, 1953) and Co deficiency in this species has been shown to be essentially a Vit. B₁₂ deficiency arising from inability of rumen microorganisms to synthesize sufficient Vit. B₁₂ when dietary Co is inadequate (Church and Pond, 1982).

Body tissues contain an average of 1.1 mg of cobalt. Of this amount 43% is stored in the muscles and 14% in the bones. The remainder is distributed among other body tissues (Underwood, 1977). Excessive accumulation does not occur in any particular organ or tissue but the liver, kidneys, and bones usually carry the highest concentrations of this element. Distribution of Co in this manner has been demonstrated in mice, rabbits, pigs, dogs, chickens, sheep and cattle with relatively small differences among species (Blokhima, 1970). Little is known of the forms in which Co exists in the tissues other than as Vit. B₁₂ and its analogues. Vit. B₁₂ contains 4.5% by weight of Co and is the biologically active form of Co (Harper, 1970; Church and Pond, 1982).

In man and non-ruminant animals, Co is mainly excreted through the urine (Harper, 1970) while in ruminants, it is predominantly excreted through the faeces (Smith and Marston 1970; Jones and Anthony, 1970).

1.2.6 Vitamin B₁₂

Vitamin B₁₂ was first described as "animal protein factor" (APF) because animals fed on diets devoid of animal protein were prone to the haematological and neurological signs that were later shown to be prevented or cured by dietary inclusion of Vit. B₁₂ (Ruckebusch et al., 1991).

Vitamin B₁₂ refers to a group of cobalamins or Vit. B₁₂ analogues viz; methylcobalamin, adenosylcobalamin, hydroxycobalamin, aquocobalamin and cyanocobalamin which have nutritional significance and have equivalent biological activity (Millar et al., 1982).

Cyanocobalamin is the cyanide derivative of aquocobalamin (AqCb1) or hydroxocobalamin (OHCb1). Hydroxocobalamin and aquocobalamin are the two naturally occurring forms produced by bacteria and are the true APF or extrinsic factor. The cyanide derivative is preferred in Vit. B₁₂ studies because of its stability. The chemical name is 5,6 dimethylbenzimidazole (Church and Pond, 1982).

1.2.6.1 Sources of Vit. B₁₂ in animal nutrition.

Rumen micro-organisms synthesize sufficient Vit. B₁₂ to meet ruminants' Vit. B₁₂ requirements when dietary Co intake is adequate (Gall et al., 1949). In ruminants, Vit. B₁₂ is absorbed mainly in the ileum (Underwood, 1977).

The bacteria in the rumen need cobalt both for Vit. B₁₂ synthesis and also for their metabolic needs. Most bacteria synthesize their sole Vit. B₁₂ but some bacteria and protozoa require Vit. B₁₂ or one of its analogues for growth (Porter, 1953). A reduction in the numbers and types of bacteria in the rumen liquor which are responsible for Vit. B₁₂ synthesis occurs in cobalt deficiency. Synthesis of Vit. B₁₂ and its analogues in the rumen is independent of feed intake but depends on Co intake in the diet (Gall et al., 1949).

Vit. B₁₂ is also synthesized by micro-organisms in the large intestine of man, dog, rat, and other animals past the absorption site. These animals therefore obtain all their B₁₂ supplies from the diet (Lester and Smith, 1965 cited by Jones and Anthony, 1970).

The source of Vit. B₁₂ in the diet varies. Carnivores obtain it from meat, particularly the offals. The vitamin is present in all animal proteins and therefore rations containing fish, bone, and meat meal, are good sources of the vitamin. Thus sufficient Vit. B₁₂ is usually present in the diet of domestic pigs and poultry (Mills, 1981).

Some Vit. B₁₂ is synthesized by soil bacteria. Rabbits and poultry may obtain the vitamin by coprophagy. The droppings of poultry do not contain Vit. B₁₂ when voided but are a potent source soon afterwards perhaps due to bacterial action on the faeces after excretion (Jones and Anthony, 1970).

1.2.6.2 Metabolism of Vit. B₁₂

It had earlier been suggested that Vit. B₁₂ and its analogues are absorbed as complexes of gastromucoproteins while the free ions of soluble Co salts pass through the walls of the small intestines (Underwood, 1975). Absorption of Vit. B₁₂ is enhanced by an enzyme (Intrinsic factor). This enzyme is secreted by the mucosal cells of the stomach, ileum and anterior region of the abomasum in ruminants. The absence of this enzyme or intrinsic factor (IF) results in Vit. B₁₂ deficiency (Church and Pond, 1982). It is suggested that the Vit. B₁₂-IF complex passes through the mucosal cells by pinocytosis before the complex is broken by a releasing enzyme; but the exact mechanism is not properly understood.

On reaching the blood Vit. B₁₂ is bound to a γ -globulin designated as transcobalamin I. If the vitamin is injected, it is bound to a β -globulin designated as transcobalamin II from which it is subsequently shifted to transcobalamin I. The exact role of each of the transcobalamins in the vitamin transport and in nutrition is not known (Church and Pond, 1982; Millar *et al.*, 1982; Price, unpublished).

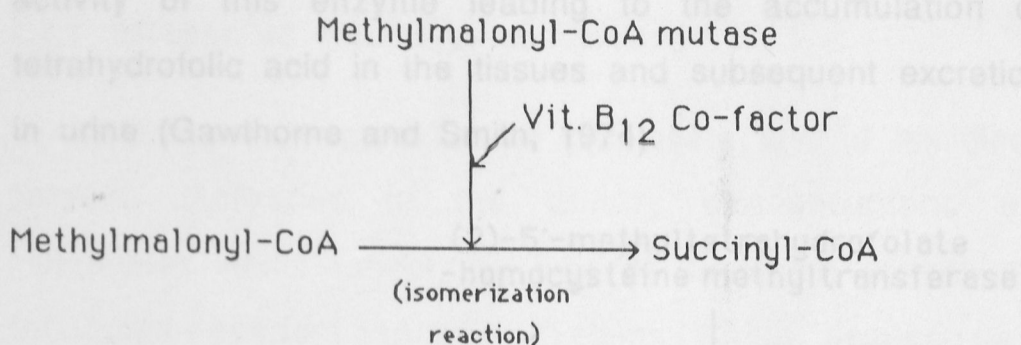
Once absorbed, Vit. B₁₂ is mainly stored in the liver and to a lesser extent, the other body tissues. In humans, 30-60% is stored in the liver, 30% in the muscles, skin, bone and smaller amounts in the other tissues. The liver, kidney and bones serve as the major storage sites in ruminants (Georgievskii *et al.*, 1981).

When the protein-binding capacity of the serum is exceeded, excretion of free Vit. B₁₂ occurs through the kidney, bile, milk and faeces (Georgievskii et al., 1981; Church and Pond, 1982; Quirk and Norton, 1982).

1.2.6.3 Biochemical Role of Vitamin B₁₂

Vitamin B₁₂ is required for some essential biochemical reactions in body metabolism; regulation of nitrogen, nucleic acids and general carbohydrate metabolism.

Vit. B₁₂ functions as a co-factor of methyl-malonyl CoA (MM-CoA) mutase enzyme which catalyses conversion of methylmalonyl CoA to succinyl CoA in propionate metabolism so that succinyl CoA enters the Krebs cycle for energy generation. This pathway requires mitochondrial adenosylcobalamin as a co-enzyme and is compromised in Vit. B₁₂ deficiency (Church and Pond, 1982). Ruminants rely on propionate metabolism as the major energy pathway and this explains the much greater B₁₂ requirements in this species compared to other species (Robertson, 1971). The primary cause of growth arrest in a cobalt deficient ruminant animal is energy failure due to impaired propionate metabolism as a result of cobalamin deficiency (Smith et al., 1967).

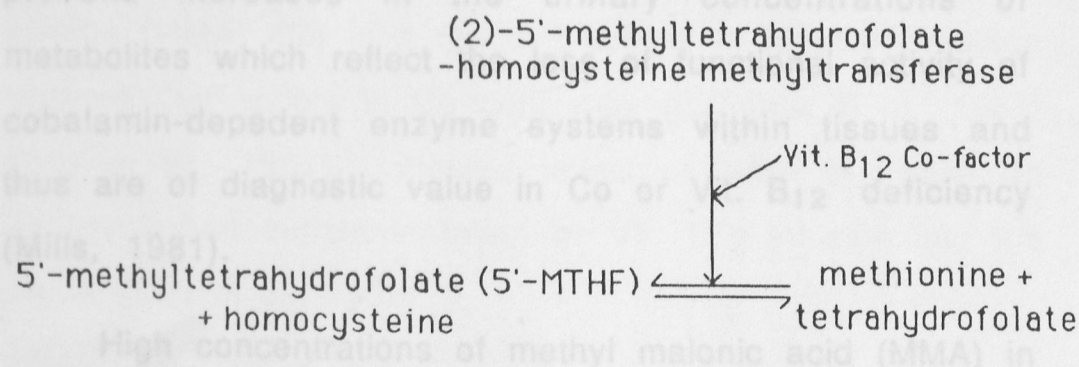


Tissue activity of MM-CoA mutase is related to the Vit. B₁₂ content of the liver, kidney, heart, brain and ruminal mucosa in lambs (Peters and Elliot, 1984). The response in the activity of this enzyme to treatment with Vit. B₁₂ in each organ depends on the amount of the enzyme activity in the particular organ. The liver possesses the greater quantitative activity of MM-Co-A mutase and is most responsive to alteration of Vit. B₁₂ status.

The more general requirement of Vit. B₁₂ in all animal species is the requirement of Vit. B₁₂ in the transmethylation reactions for generation of methyl groups in the synthesis of 1-carbon compounds; methionine, methane, and acetate formation from carbon dioxide (Ruckebusch et al., 1991). The methyltransferase system requires methylcobalamin as a coenzyme.

The complete metabolism of histidine to glutamate involves an intermediate metabolite, formiminoglutamate (FIGLU). The conversion of FIGLU to glutamate is catalysed by the enzyme, methyltetrahydrofolate-homocysteine transmethylese which requires Vit. B₁₂ as co-factor. In cases of Vit. B₁₂ deficiency, there is a decline in the

activity of this enzyme leading to the accumulation of tetrahydrofolic acid in the tissues and subsequent excretion in urine (Gawthorne and Smith, 1974).



The system depends on the affinity of cobalamin for methyl groups. A cyclic reaction is primed by Vit. B₁₂ forming methylcobalamin, which transfers the methyl group from methyltetrahydrofolate (MeTHF) to homocysteine, forming methionine while Vit. B₁₂ is regenerated and repeats the cycle having returned a methyl group to tetrahydrofolate (THF). This forms the link between Vit. B₁₂ and folate metabolism. In Vit. B₁₂ deficiency, the MeTHF cannot be restored to THF and builds up in the plasma and is excreted in urine (Harper, 1970). Methionine synthesis falls in cobalt deficiency leading to decreased protein retention, wasting and poor wool and hair growth (Gawthorne and Smith, 1974).

Vit. B₁₂ is involved in reduction of ribonucleotides to deoxyribonucleotides in erythropoiesis but the mechanism is not known (Georgievskii et al., 1981).

1.2.7 Effects of Vit. B₁₂ deficiency

Interrupted degradation of propionate and of histidine provoke increases in the urinary concentrations of metabolites which reflect the loss of functional activity of cobalamin-dependent enzyme systems within tissues and thus are of diagnostic value in Co or Vit. B₁₂ deficiency (Mills, 1981).

High concentrations of methyl malonic acid (MMA) in plasma and urine occurs in severe Vit. B₁₂ deficiency and formiminoglutamate (FIGLU) excretion in urine reflects lack of Vit. B₁₂ in the tissues. This has been used as a diagnostic tool for Vit. B₁₂ deficiency in sheep (Gawthorne, 1968; Millar and Lorentz, 1979; Judson et al., 1982). The marked increase in FIGLU excretion in the initial stages of Vit. B₁₂ deficiency suggest that the metabolic reactions involving this compound are impaired relatively early in the development of the deficiency syndrome (Gawthorne, 1968; Russel et al., 1975). Quirk and Norton (1987) observed that urinary FIGLU concentration is a more reliable indicator of Vit. B₁₂ status in lambs than MMA concentration.

The biochemical pathway leading to FIGLU urinary excretion involves incomplete metabolism of histidine to glutamate (Mills 1981). This occurs due to failure or reduced activity of the (cobalamin-dependent) methyltetrahydrofolate-homocysteine transmethylese enzyme leading to accumulation of formiminoglutamate in

the tissues and subsequent excretion in urine (Gawthorne and Smith 1974).

Co deficient sheep and goats develop high levels of plasma (MMA) due to a reduced activity of MM-CoA mutase enzyme that occurs in Co deficiency (Cannata et al., 1965; Rice et al., 1987). Plasma levels of MMA decrease on dietary cobalt supplementation or Vit. B₁₂ infusion into the blood (Rice et al., 1989).

The formation of methyl-malonyl CoA (MM-CoA) from propionyl CoA is not affected by Vit. B₁₂ deficiency but is affected by the amount of propionate absorbed from the alimentary canal (Marston et al., 1961). Thus the potential accumulation of MMA and augmented urinary MMA excretion in the initial stages of deficiency may be offset by a progressive decrease in amount of propionate presented for metabolism within the animal as daily feed intake declines. The elevated excretion of MMA in the later stages of deficiency suggest that MM-CoA isomerization becomes so severely impaired by Vit. B₁₂ deficiency that sheep are no longer able to isomerize the decreasing quantities of propionate which decreases with decreasing feed intake in cobalt deficiency (Marston et al., 1961).

A rise in urinally excretion of MMA (Gawthorne, 1968) has been found to be a more sensitive indicator of onset of Vit. B₁₂ deficiency than weight loss. Millar and Lorentz, (1979) reported a rise in urinally MMA a month before impairment of weight gain in lambs.

In Vit. B₁₂ deficient sheep alternate hepatic metabolic pathways for accumulated plasma MMA has been suggested (Peters et al., 1983). Excess MMA is utilized in fatty acid elongation giving rise to branched chain fatty acids. Unmetabolised propionate becomes a primer for fatty acid biosynthesis giving branched chain fatty acids which accumulate in the liver, a condition referred to as fatty degeneration (Duncan et al., 1981). In sheep and goats, the condition is termed "white liver disease" (Black et al., 1988; Ulvund, 1990). Low serum and liver Vit. B₁₂ levels and low dietary cobalt availability are associated with this disease in sheep (Sutherland et al., 1979; Ulvund, 1990). This suggesting that WLD is a metabolic consequence of Vit. B₁₂ deficiency in ruminants on a diet high in propionate precursors.

Co deficiency causes impairment of reproductive function which is similar to that caused by malnutrition in domestic animals (Gombe and Verjee, 1976; Musewe and Gombe, 1980). In Co deficient goats, impairment of hypothalamic functions have been observed which possibly lowers the sensitivity of target organs involved in reproduction (Mgongo, 1979).

The initial stages of cobalt deficiency are associated with pituitary hyperplasia and hyperactivity with concomitant elevation of plasma levels of trophic hormones which decline in later stages (Mgongo et al., 1978 cited by Musewe and Gombe, 1980). Gonadotrophic hormones are

elevated early in deficiency whilst adrenal corticotrophic hormone (ACTH) and thyroid stimulating hormone (TSH) elevation occurs later. These effects of cobalt deficiency are not completely offset by energy or protein supplementation (Mgongo, 1979).

The high incidence of stillbirths and perinatal mortality reported in lambs born to deficient ewes (Duncan et al., 1981) is related to disorder of the lamb's immune function by cobalt deficiency (Fisher and Macpherson, 1986). In cobalt deficient calves, Macpherson et al. (1987), demonstrated a depression in neutrophil function which probably reduced the calves' resistance to diseases.

1.2.8 Requirements for cobalt and Vitamin B₁₂ in Ruminants

The requirements of animals for cobalt are expressed in proportions such as parts per million, (ppm) or mg/kg of dry matter. They have been expressed in amounts per day, per unit of product such as milk, eggs and also per unit weight gain. Another way is to use concentrations in plasma and tissues e.g. liver, kidney e.t.c. Concentrations in tissues and plasma have been considered to be more precise and are independent of variations of total feed intake (Underwood, 1981).

The adequacy or Co status of ruminants is influenced by species differences (Underwood, 1981; Clark et al.,

1987). Other factors affecting Vit. B₁₂ requirements include the production and reproduction levels, e.g. Vit. B₁₂ requirements for reproduction are higher than for body growth (Underwood, 1981). High yielding daily cows may require higher levels of Vit. B₁₂ than low yielding ones (Quirk and Norton, 1982).

(i) Pasture cobalt requirements

Pastures cobalt content of 0.035 mg/kg DM has been observed to induce Co deficiency in sheep (Clark et al., 1987). This level of pasture Co failed to give a decrease in body weight response in goats suggesting that pasture Co requirements for goats may be lower than for sheep. Mburu (1991), reported a sub-clinical Co deficiency status after feeding goats on hay containing 0.02 mg Co/kg Dm for 23 weeks. Co deficiency was induced in the small East African goat by feeding a diet containing 0.01 mg Co/kg DM during which anaemia and weight loss were observed (Mgongo et al., 1981). These findings were in agreement with those of Clark et al. (1987). Cattle and deer have also been shown to have lower dietary Co requirements than sheep (Clark et al., 1987).

(ii) Serum Vit. B₁₂ requirements

Goats fed on pasture containing 0.035 mg Co/kg Dm had serum Vit. B₁₂ concentration in the marginal range for sheep (185-370 pmol/l) (Clark et al., 1987). Mgongo et al., (1981) recorded serum Vit. B₁₂ concentrations of below 100 pg/ml in Co deficient goats under laboratory conditions

while Co adequate control goats had levels above 400 pg/ml.

A mean serum Vit. B₁₂ concentrations of 142.8 ± 28.27 pg/ml in Co deficient goats compared to 286 ± 40.76 pg/ml in Co adequate counterparts have been reported in a controlled laboratory experiment (Mburu, 1991). Deficient goats had serum Vit. B₁₂ concentrations ranging from 235 ± 76.05 pg/ml at the start of the experiment to 81.1 ± 28.27 pg/ml by the ninth week of feeding a Co deficient diet. Co supplemented goats increased their serum Vit. B₁₂ concentrations from 231.3 ± 92.67 pg/ml at the start of the experiment to 386.9 ± 97.97 pg/ml by the 10th week on a Co deficient diet. Despite high variations in serum Vit. B₁₂ levels, these findings show that a decline below 200 pg/ml is indicative of Co deficiency status in goats.

The finding that Co supplemented goats had consistently high serum Vit. B₁₂ levels, than unsupplemented goats suggests that as in sheep (Findlay, 1972), serum B₁₂ concentrations in goats reflect the level of dietary Co. Mburu (1991), found that significant impairment on body conditions in goats fed on Co deficient diet occurs after serum Vit. B₁₂ levels have declined to below 200 pg/ml. This suggests that goats are more resistant than sheep to low dietary Co and that the lower reference range for serum Vit. B₁₂ should be regarded as being below 200 pg/ml.

(iv) In sheep, serum Vit. B₁₂ levels below 200-300 pg/ml are indicative of deficiency status (Underwood, 1977; Tressol and Lamand, 1979). Levels of upto 1275 pg/ml have been recorded in cobalt adequate sheep (Tressol and Lamand, 1979). Cobalt deficiency in cattle has been associated with serum Vit. B₁₂ levels less than 200 pg/ml (Winter et al., 1977). Macpherson (1981) observed that cattle were able to maintain serum Vit. B₁₂ levels lower than 100 pg/ml without any impairment on growth.

(iii) Liver Vit. B₁₂ concentrations

Liver Vit. B₁₂ concentrations corresponding to different degrees of deficiency have been defined on the basis of weight responses to cobalt supplementation. Andrews, (1965) concluded that hepatic Vit. B₁₂ levels below 0.1 µg/g of liver from individual sheep indicates a definite cobalt deficiency. Marston (1970), reported that loss of appetite in penned sheep occurred when liver Vit. B₁₂ levels fell to 0.1 µg/g. A value of 0.2 µg/g has been taken as an approximation of the minimum liver Vit. B₁₂ concentration ("critical level") above which cobalt deficiency is unlikely to occur (Andrews et al., 1959; 1960). This value is in agreement with "critical" values of 0.2 µg/g of liver reported by Millar and Penrose (1980). Correlation between liver and serum Vit. B₁₂ values for individual sheep is low (Millar and Alby (1984) suggesting that serum Vit. B₁₂ cannot be used to predict the livers' vitamin storage.

(iv) Levels of MMA and FIGLU in urine and plasma of cobalt adequate and deficient ruminants

In an experiment to evaluate the usefulness of serum Vit. B₁₂ concentrations and the concentrations of urinary MMA and FIGLU as indicators of Co deficiency in lactating heifers and their calves, Quirk and Norton (1987) found that the urine of Co supplemented heifers was free from detectable levels of both FIGLU and MMA (i.e. greater than 30 and 80 $\mu\text{mol/l}$) respectively. Levels of 75 ± 31 $\mu\text{mol/l}$ urinary FIGLU and 1254 ± 678 $\mu\text{mol/l}$ urinally MMA were observed in Co deficient heifers.

Calves from Co adequate heifers excreted very low urinally concentrations of FIGLU (0-62 $\mu\text{mol/l}$) throughout the experimental period. Co deficient calves increased urinary FIGLU concentrations from 500 $\mu\text{mol/l}$ at birth to 2000 $\mu\text{mol/l}$ at 12 weeks of age. These levels decreased to less than 100 $\mu\text{mol/l}$ at 18 weeks and at 24 weeks their urine was free of detectable concentrations of FIGLU. The urine of calves from supplemented heifers was free of MMA during the experimental period. Urinary FIGLU was found to be a more reliable indicator of Vit. B₁₂ deficiency in suckling calves than urinary MMA concentrations.

Urinary concentrations of MMA is negatively correlated with serum Vit. B₁₂ and Co status in sheep (Gawthorne, 1968; Millar and Lorentze, 1979; Judson et. al., 1982; Rice et al., 1987). Lambs from Co deficient ewes have been shown to have detectable concentrations of MMA

(greater than 80 $\mu\text{moles/l}$) and FIGLU (greater than 30 $\mu\text{moles/l}$) in their urine (Andrews and Stephenson, 1966; Underwood, 1977).

It has been found that plasma MMA remain below 5 $\mu\text{mol/l}$ in lambs whose plasma Vit. B₁₂ levels are kept above 190 pmol/l (Rice et al., 1989) but when plasma Vit. B₁₂ levels are kept below 190 pmol/l, plasma MMA levels increase to above detectable levels.

(v) Production responses to cobalt supplementation

In a Co supplementation response trial, Norton and Hales (1976) found that Co supplemented ewes lost significantly less weight ($p < 0.05$) during lactation than unsupplemented controls. This suggests that unsupplemented ewes drew heavily on body tissues to meet the demands of lactation than Co supplemented ewes. Lambs from supplemented ewes showed higher and more sustained growth during post-natal period than those from unsupplemented control ewes.

A controlled laboratory study to investigate the relationship between Co nutrition of ewes and the occurrence of Vit. B₁₂ deficiency in ewes and their lambs by Quirk and Norton (1987) revealed that a dietary cobalt intake of about 0.15 mg/day is necessary for optimal milk production in ewes. The ewes were on pastures containing 0.05 and 0.11 mg Co/kg DM. An increase in live weight, reproductive and lactation performance was observed when the ewes were supplemented with a cobalt drench while

milk production increased with increasing levels of Co supplementation.

Cobalt supplemented ewes were heavier during pregnancy and produced heavier lambs at birth compared with unsupplemented controls (Quirk and Norton, 1987). Milk production of the ewes and the growth of their lambs was increased by increasing levels of Co in the diet of the dams. Lower productivity was associated with levels of serum Vit. B₁₂ of less than 200 pg/ml in the ewes.

Based on liveweight gain response to cobalt supplementation in sheep, the production reference ranges are divided into 3 categories; Deficient or (responsive) range in which production response invariably occurs; adequate in which a response rarely occurs; and a marginal range in which a response may or may not occur (Clark et al., 1984). In the marginal and low range the degree of response increases with decreasing serum levels Vit. B₁₂ concentrations. Low or responsive range corresponds to serum Vit. B₁₂ concentrations lower than 180 pmol/l, the marginal range corresponds to serum Vit. B₁₂ levels in the range, 180-370 pmol/l and Co adequate status corresponds to serum Vit. B₁₂ levels above 370 pmol/l (Clark et al., 1984).

The administration of cobalt bullets to pregnant heifers grazing pastures containing between 0.03 and 0.05 mg Co/kg had no effect on liveweight nor milk production and birth-weight of calves (Quirk and Norton, 1988). These

authors found no significant differences in concentrations of total solids, protein or fat in the milk between supplemented and control heifers but the Vit. B₁₂ concentration in milk from supplemented heifers was significantly greater ($p < 0.05$) than that from control heifers at each milking.

Quirk and Norton, (1982) showed that cobalt supplementation of heifers during pregnancy does not significantly affect birth weight of calves; but subsequent liveweight gain of calves from supplemented heifers is significantly higher than of calves from unsupplemented heifers. These results showing that the cobalt requirements of heifers' optimal growth of their calves is higher than their own requirement for growth and lactation. This suggested that production responses occur when the animals' cobalt status (tissue concentrations) are depleted and response trials can be used in diagnosis of prolonged deficiency.

1.2.9 Diagnosis of Vit. B₁₂ deficiency

1.2.9.1 Clinical diagnosis

The clinical signs together with laboratory tests and sometimes dietary analysis are used to reach a conclusive diagnosis of Vit. B₁₂ deficiency. The clinical signs developed depend on animal's age, its Vit. B₁₂ status and the amount of cobalt in the diet (Underwood, 1981). Young

ruminants develop signs more easily than adults e.g. development of the deficiency in four weeks has been reported in lambs born to deficient ewes and raised on cobalt deficient pastures (Quirk and Norton, 1987).

The signs observed in sheep and other ruminants include gradual loss of appetite (Dawbarn et al., 1957) leading to decreased growth rate (Quirk and Norton, 1982), weight loss (Smith and Marston, 1970), extreme inappetence leading to rapid muscular wasting, pica or depraved appetite, anaemia and death (Underwood, 1981; Mills, 1981).

Decreased liveweight gain, muscular atrophy, lethargy, emaciation and loss of body condition are due to decreased feed intake as a result of anorexia resulting from Vit. B₁₂ deficiency (Zahari et al., 1983). Anaemia has been reported to occur in prolonged deficiency manifested by pale mucous membranes (Underwood, 1981). These changes lead to an overall decrease in production manifested mainly as poor body conditions, decreased reproductive performance and anaemia (Mgongo, 1979; Underwood, 1981; Mgongo et al., 1984; ; Peters and Elliot, 1983).

In lambs photosensitization occurs (Sutherland et al., 1979; Mchoughlin et al., 1984), while long standing cases in sheep show nervous signs (Macpherson et al., 1976).

Decreased immunity and high susceptibility to ostertagia infestation has been demonstrated in deficient calves compared to supplemented controls (Macpherson et al., 1987). Chronic worm infestation depresses Vit. B₁₂

reserves in subclinically deficient animals to levels enough to cause overt deficiency in sheep (Downey, 1966).

There is no specific clinical sign upon which diagnosis can be based. The absence of pathognomonic features of the syndrome at stages when appetite, growth, or viability of the newborn are impaired is probably the most important cause of continuing losses from cobalt deficiency (Underwood, 1981).

Body Condition

Body condition can be defined as the level of an animal's body reserves of energy and nutrients, which is determined by the balance between demands for energy and nutrients and their supply. Demand varies with growth stage, sex, reproductive status, while supply varies seasonally in terms of both quantity and quality (e.g. protein energy, fat, mineral and vitamin content and digestibility) (Skea, 1988).

In adult goats, changes in body condition are reflected by the deposition, and mobilization of fat reserves and gain or loss of body mass or muscle enlargement while in growing animals, changes in condition are reflected in the variation of growth rates (Skea, 1988).

The loss of body condition in Co or Vit. B₁₂ deficiency has been reported widely over the world including East Africa (Mgongo et. al. 1984; Mgongo, 1979; Musewe and Gombe, 1980). Decreased weight gain has been used as a

diagnostic index of cobalt or Vit. B₁₂ deficiency (Rice et al., 1989). Ewes and lambs fed on cobalt deficient diet were found to become unthrifty and failed to reproduce when their serum Vit. B₁₂ levels were in the normal range (Quirk and Norton, 1987).

Anaemia in Cobalt Deficiency

Anaemia has been reported to occur in cobalt deficient goats and cattle (Gombe and Verjee, 1976; Mgongo, 1979; Musewe and Gombe, 1980). The anaemia was manifested as decreased haemoglobin levels, decreased packed cell volume (PCV) and decreased red blood cell count (Gombe and Verjee, 1976). Mgongo et al. (1981) recorded no change in white blood cell counts but there was marked lymphopenia and neutrophilia in Co deficient goats.

Anaemia in vitamin B₁₂ deficiency has been described to be macrocytic (Gombe and Verjee, 1976) and macrocytic and normochromic (Mgongo et al., 1984). It was noted that improvement in the blood picture after cobalt supplementation may be delayed and occurs after an improvement in appetite and body weight has occurred (Mgongo et al., 1984). This suggests that anaemia may be secondary to a loss of appetite.

In an attempt to study the mechanism by which Vit. B₁₂ deficiency causes anaemia, it was found that the activity of erythrocyte glutathione peroxidase enzyme is increased in Vit. B₁₂ deficiency anaemia but the same enzyme activity decreases in iron deficiency anaemia

(Gombe and Verjee, 1976). The levels of glutathione reductase (GSH) increases in both cases.

When deficient goats are given cobalt as a supplement in their diet, PCV starts rising but GSH levels takes sometime and then starts decreasing. This suggested that the anaemia and enzyme changes were caused by cobalt deficiency and that the mechanism by which Vit. B₁₂ deficiency causes anaemia could be related to the activities of these enzymes (Gombe and Verjee, 1976) .

Human beings with Vit. B₁₂ deficiency anaemia have increased levels of GSH similar to that in Vit. B₁₂ deficiency in cattle (Chanarin, 1977). Increased GSH levels is thought to be compensatory to prevent loss of haemoglobin through oxidative destruction. The exact mechanism by which Vit. B₁₂ affects the haemopoietic system is not known but it is compared to the effects of folate.

Folate is concerned with purines and pyrimidines; RNA and DNA synthesis and deficiency leads to failure of DNA synthesis (Chanarin, 1977). In Vit. B₁₂ deficiency, the bone marrow cells have DNA content of between 2C (chromosome content) and 4C. These cells die in the bone marrow and are reabsorbed. Some of the cells mature into macrocytic erythrocytes. The bone marrow may remain normoblastic and later in the course of the disease some hypoplasia may occur (Chanarin, 1977).

Reproductive performance and related endocrine functions.

By affecting body condition, growth rate, body weight at the onset of puberty, Co deficiency delays onset of oestrus and reduces the reproductive performance in domestic ruminants (Skea, 1988).

A few studies of controlled experiments have reported the effects of cobalt deficiency upon reproductive performance. In Co deficient goats, oestrous cycles of widely varying durations have been observed (Mgongo et al., 1984). Induced cobalt deficiency in goats caused oestrous cycles of 26.6 ± 0.8 days, (maximum deviation 12 to 38 days) compared to 18 ± 0.3 days, (maximum deviation 16 to 21 days) in Co adequate goats. Prolonged deficiency led to anoestrus (Mgongo et al., 1984).

Duncan et al. (1981) demonstrated that prolonged exposure of sheep to a low cobalt diet resulted in high perinatal and still birth losses in lambs. Fisher and Macpherson (1986) observed high rate of neonatal mortality of lambs born to ewes which were not supplemented with Co throughout pregnancy. Poor health was observed in lambs of ewes which were Co supplemented upto mid-pregnancy and then deprived to birth. This suggests that Co deficiency in ewes leads to reduced viability and impairment of the lambs ability to resist infections.

Lowered conception rates of 30% in Co deficient cattle and high calf mortality leading to an overall decrease

in reproduction has been described in poorly managed farms of the endemically Co deficient region of the Rift Valley of Kenya (Musewe and Gombe, 1980).

An impairment of the endocrinological control mechanism is suggested to lead to the irregular cycles observed in Co deficiency. It is speculated that the affected site is located in the hypothalamo-pituitary axis (Mgongo et al., 1984). These authors observed increased concentration of plasma progesterone which decreased during the third and subsequent cycles in cobalt-deficient goats as compared to controls while pituitary leutenizing hormone (LH) was low in Co deficient goats. Plasma levels of progesterone and total unconjugated oestrogen decrease in cobalt deficient goats (Mgongo, 1979). Corpus luteum progesterone levels were lower in Co deficient than Co adequate goats (Mgongo et al., 1984).

In the ovary, primordial cell follicles and thecal cells of secondary and tertiary follicles showed atrophy in Vit. B₁₂ deficiency (Mgongo et al., 1984). The ovaries of co deficient goats showed hypertrophy of ovarian stroma and absence of corpora lutea while ovarian weights were lower in Co deficient than Co adequate goats (Mgongo, 1979). Other endocrine glands including the adrenal and thyroid glands showed hypertrophic and hyperplastic changes in Co deficient animals (Mgongo et al., 1981). This was associated with stress induced by Vit. B₁₂ deficiency and has been supported by the increase in the levels of

iodothyronines (T3 and T4) and corticosteroids caused by Vit. B₁₂ deficiency (Mgongo et al., 1984).

1.2.9.2 Laboratory Diagnosis

(i) Laboratory Diagnosis by analysis of Vit. B₁₂ concentration in the tissues

The brain, liver, heart and kidney levels of Vit. B₁₂ have been used in diagnosis of Vit. B₁₂ deficiency (Peters and Elliot, 1984). In this method, tissue homogenates are prepared in a cold room (4°C) with controlled light to minimize photolytic degradation of Co-enzyme B₁₂. Homogenates for determination of Vit. B₁₂ are prepared by centrifugation of a weighed piece of tissue at 10,000 rpm for one to five minutes. The homogenate is diluted 1 in 50 with buffer.

Later, Vit. B₁₂ is extracted by steaming the homogenate in the presence of potassium cyanide and then quantified by a competitive binding radioassay e.g. Radiochemical centre assay method (Millar and Penrose, 1980). Samples are stored at -20°C between analysis.

(ii) Microbiological methods

Microbiological methods for diagnosis of Vit. B₁₂ deficiency have been used in the past (Millar and Penrose, 1980). These methods involved the measure of bacterial activity of some bacteria which are sensitive to Vit. B₁₂ for

example, Escherichia coli, Lactobacillus leishmannii and Ohromonas mahlemensis (Underwood, 1977). This method was used for analysis of Vit. B₁₂ concentrations in the sera and livers of both sheep and cattle (Millar et al., 1982).

In the past serum Vit. B₁₂ was extracted by steaming for 20 minutes a mixture of 1.0 ml serum, 1.0 ml 0.1M sodium acetate buffer (pH 4.6) and 6.0 ml water containing 0.1% (w/v) solution of potassium cyanide. After cooling, the mixture is diluted to 10 ml and the precipitated protein removed by centrifugation. Suitable aliquots of the liver or serum extracts are then analysed for Vit. B₁₂ using L. leichmannii microbiological method developed by Krieger (1954 cited by Millar and Penrose, 1980). Millar et al. (1982) reported results of serum and liver Vit. B₁₂ concentrations by the microbiological assay methods that correlated significantly ($r > 0.88$; $p < 0.01$) with those obtained by the radioassay in previous findings (Millar and Penrose, 1980). In cases where discrepancies were noted between values obtained by the two methods, these were attributed to the presence of Vit. B₁₂ analogues in some samples (Kolhouse et al., 1978).

Andrews (1965) acknowledged the limitation of the microbiological assay in cases of mild and intermittent cobalt deficiency. Andrews, (1970) observed that serum Vit. B₁₂ levels as estimated by the microbiological techniques are subject to variation which limited result interpretation.

(iii) Estimation of plasma or urinary MMA and FIGLU

In these methods, MMA is extracted in ethyl acetate and the concentrated extract esterified using butanol or acetyl chloride. The butyl esters are then extracted in hexane separated and quantified using capillary gas or liquid chromatography. Methyl silicon is used as the stationary phase. This method was shown to separate and quantitate MMA by McMurray et al. (1986 cited by Rice et al., 1989).

(iv) The Radioassay method

Radioassays are based on the competition between the substance to be measured and a fixed quantity of radioactively labeled tracer for a limited number of specific binding sites. In this assay, serum Vit. B₁₂ competes with ⁵⁷Cobalt-labeled Vit. B₁₂ for sites on purified intrinsic factor.

The sample is mixed with tracer and incubated with denaturation reagent (Amersham, Labs.) at pH 12.8-13.0 which irreversibly denatures the binding proteins and releases Vit. B₁₂ from serum binding proteins. The samples are then incubated at pH 9.5 with a solution containing purified hog intrinsic factor or binding protein. The separation of the protein bound fraction is achieved by adsorption of the free fraction on coated charcoal. After centrifugation the supernatant liquid is counted in a suitable gamma counter. The concentration of Vit. B₁₂ in unknown sample is interpolated from standard curves,

derived from reference solutions containing known concentrations of Vit. B₁₂.

Millar and Penrose (1980) did tests with radioassay kits from different manufacturers to ascertain the replicability of results. For all methods the recovery of added Vit. B₁₂ was greater than 92%. These authors showed that the radioassay method is as reliable as the microbiological method for measuring Vit. B₁₂ in the livers of sheep. They also showed that the radioassay method is faster than the microbiological method, is not subject to problems of sample contamination and that at low plasma Vit. B₁₂ concentrations, the radioassay method may be more sensitive than the microbiological assay.

Limitations

The serum Vit. B₁₂ levels for cattle as indicated by various authors are below 200 pg/ml (Winter et al., 1977) and lower than the 200 pg/ml requirement for sheep (Underwood, 1977; Mburu, 1991). Increases in plasma Vit. B₁₂ following cobalt supplementation have been reported to be unexpectedly low in the bovine whether determined by the microbiological or radioimmuno assays designed for human plasma (Price, unpublished).

Since both types of assay depend on the effective displacement of cobalamin from specific binders (transcobalamins, TC), the above anomalies have been explained by incomplete release of the vitamin from its binders (Price, unpublished). It was observed that a

substantial proportion of the labeled Vit. B₁₂ in bovine plasma equal to that bound to TC 0 and TC 1 remained bound to the protein binders after treatment potassium cyanide at 95°C previously used to release Vit. B₁₂ from the protein binders (Price, unpublished). This treatment was found to be completely effective in displacing the labelled vitamin from human TC1 and TC2 and sheep TC2. These findings suggest that while Vit. B₁₂ in sheep plasma may be determined satisfactorily by competitive binding assays designed for use in man, they may underestimate the concentration of the vitamin in cattle plasma if TC 1 is quantitatively important as a Vit. B₁₂ binder in the bovine and this could result in the much lower values in cattle compared to the other ruminant species. It is not known what binders are present in goat plasma and whether the binders could be responsible for the low values obtained in this species (Clark et al., 1987; Mburu, 1991).

1.2.9.3 Differential diagnosis

The unthriftiness that occurs in cobalt deficiency is likely to be confused with gastrointestinal parasites, copper deficiency or inadequate nutrition (Findlay, 1972). Gastrointestinal parasitism can predispose cobalt deficiency and worm burdens can precipitate cobalt deficiency in areas of marginal deficiency (Downey, 1966).

Determination of dietary cobalt and serum Vit. B₁₂ levels, urinally MMA and FIGLU concentrations combined

with the clinical observations provide conclusive diagnosis of Vit. B₁₂ deficiency in sheep (Rice et al., 1987) and humans (Lindenbaum et al., 1988).

1.2.10 Prevention and Treatment of Cobalt Deficiency in ruminants

There is a wide variety of therapeutic and preventive therapies available for cobalt deficiency in ruminants. They are classified into direct and indirect methods. Both methods can be applied simultaneously (Underwood, 1981). The indirect methods include top-dressing of pastures with fertilizers containing trace elements (Black et al., 1988) and soil ammendments that affect mineral composition of pastures and feeds. The indirect method is limited by high cost (Underwood, 1981).

Direct methods include dietary supplementation by administration of cobalt salts as a drench, as cobalt sulphate (Findlay, 1972) or in drinking water or rations, mineral salt licks, parenteral injection of the trace element, or of Vit. B₁₂ (Black et al., 1988, Millar and Penrose, 1980), and recently administration of intra-ruminal 'bullets' or soluble grass boluses (Telfer et al., 1984; Zervas et al., 1988). The benefits of these methods have been reviewed extensively (Underwood, 1977). They vary in cost, convenience and effectiveness.

Supplementation by inclusion of cobalt supplements in oral anthelmintics has been practised. This has the advantage that the handling of the animals is minimised and the trace elements are given automatically during dosing of anthelmintics. This method has been in use particularly in the United Kingdom (Bremner et al., 1988).

Oral administration of cobalt to sheep has been shown to cause a rise in Vit. B₁₂ in serum within 24 hours. The carbonate, chloride, sulphate and nitrate salts are considered satisfactory dietary sources of cobalt (Findlay, 1972). The inefficiency in improving weight gain recorded by Zahari et al. (1983) using oral cobalt supplementation could be due to poor absorption of the salt in the intestines and thus greater excretion in faeces as suggested by Underwood (1977).

Injection of Vit. B₁₂ or hydroxocobalamin has been used in many experimental trials as a means of supplementation and treatment in the studies and diagnosis of Vit. B₁₂ deficiency (Millar and Penrose, 1980; Black et al., 1988). Hannam et al. (1980), reported that a single injection of hydroxocobalamin prevented signs of cobalt deficiency in lambs and weaners. Vit. B₁₂ injection reduces the dependence of the animals on microbial Vit. B₁₂ synthesis in the rumen and is more efficient than oral cobalt in causing increase in live weight gain (Zahari et al., 1983). However, this method may not be practicable in

ruminants reared normally due to frequency of injection and inconvenience in restraining the animals.

The supplementation methods chosen will depend on the system of husbandry, the species, breed, age of animal at risk and the degree of deficiency encountered on the farm. The most convenient method of treatment is one in which all of the animals receive the prescribed amount of trace element but frequency of handling the animals is minimised. The supplement therefore must provide a source of the element for over a long period of time, say an year. To accomplish this a relatively large amount of the element must be given in a single dose in a form which is not toxic to the animal.

Cobalt supplementation indirectly or by boluses is considered to be the most economical method of both treatment and prevention of the cobalt deficiency in ruminants (Underwood, 1981). Cobalt boluses have been shown to be effective in maintaining high serum Vit. B₁₂ concentrations for period of one year (Zahari et al., 1983; Telfer, et al., 1984). The boluses or pellets are placed within the reticulorumen by a balling gun and dissolve at a slow rate determined by the surface area of the bolus exposed to the rumen medium.

Trials have shown that these boluses can prevent or cure cobalt deficiency in sheep and cattle (Telfer et al., 1984) and in grazing lambs (Zervas et al., 1987). Zervas et al., (1988) found that the treatment of pregnant animals

with the cobalt boluses can successively prevent the deficiency for about an year and also gives protection to the foetus and the young lamb in its early life.

In the rumen, boluses tend to have a calcium coating which reduces the effectiveness of this mode of supplementation (Andrews et al., 1958). Boluses are also lost by regurgitation (Millar and Andrews, 1964) but these losses have been reduced by increasing the density of pellets by reducing their cobalt oxide content from 60% to between 30-40%. Administration of grinders together with the pellets reduces surface coating with calcium phosphate (Whitelaw and Russel, 1979).

In areas where clinical cobalt deficiency is easily recognizable, Co supplementation is necessary (Norton, 1984). Where the deficiency does not manifest clinically, careful investigation over a period of time may allow mapping out varying degrees of deficiency in an area and effects of deficiency lessened by improved grazing management. Top dressing of small localized areas may be possible and even dosing the animals regularly with Co-incorporated anthelmintics (Underwood, 1981). The benefits of supplementation with cobalt bullets should be weighed against the cost of treatment.

1.2.11 On-Farm Research

On farm research involves an association with the farmers and allows better understanding of the farming systems, management constraints and identification of the problems encountered in the farm (Nordblom et al. 1985). Thus they bridge the gap between controlled laboratory studies and the successful adoption of improvements in livestock production.

Problems encountered during On-Farm Research

Knipscheer (1985) highlighted some of the problems encountered during on-farm research. In cases where the scientist tries to be responsive to the farmers' needs, identifying strongly with them or their families, the scientists might find themselves outside their research mandate because the farmers lack knowledge about research possibilities and limitations.

In the case of substantial government inputs say in finances and personnel, the on-farm evaluation might yield short-lived benefits which last for as long as the government is able to maintain the project (Knipscheer, 1985).

Other problems relate to the designs of on-farm studies and in the evaluation of results.

Experimental designs of on-farm studies

Procedures and designs used in laboratory experiments e.g. randomization of farms and animals into groups, within groups and running of the groups together during the study do not apply in on-farm conditions (Pervaiz and Knipscheer, 1989; Van Eys, 1985). The lack of control and complexity of the farm situation forces experimental design to meet practical requirements and facilitate the interpretation of the results, e.g. essential information on farm and production conditions must be gathered (Pervaiz and Knipscheer, 1989).

Criteria that precludes random selection are: willingness of farmers to cooperate which depends on the relevance of the research problem to the farmer, levels of education, interest, experience with animals, interest in research results and previous experience in research e.t.c. Suitability of farms in the experimental design, social standing of farmers in the community, access to the man or woman in charge of the production process e.t.c. also determine farm selection (Van Eys, 1985; Pervaiz and Knipscheer, 1989).

The response variable to be measured can influence the experimental design. For example, a study of responses in fertility trends needs more animals per group than one looking at live weight responses (Clark, et al., 1984). Fewer animals per group are required in studies on tissue levels of an element or metabolite in mineral nutrition. The number

of animals to be included also depends on practical considerations like accessibility of the farm and target animals and under some circumstances, it may be better to have fewer animals than no study at all (Clark, et al., 1984).

Compensation for the risk taken by the livestock producer is an important consideration. This can be in form of feed for animals, cash, food, assistance in disease control of the animals, technical advice e.t.c. Monetary compensations should be avoided (Knipscheer, 1985).

Methods of on-farm Research

It has been shown that information relating to geographical spread of target animals and their number and type is useful in guiding data collection (Pervaiz and Knipscheer, 1989). This reflects on the coverage of the survey and guides in estimating the materials, human resources and time available for the study. A list of target livestock operators and their locations is useful in guiding the researchers' movements in the first few days of the survey.

A questionnaire may be used as an aspect of methodology (Saad, et al, 1985) and the questions should be short and precise covering both qualitative and quantitative aspects e.g. location, number of animals and rations used, methods of feeding, watering, main feed, disease problems, seasonality operations and other aspects related to

management and production of animals. A coded format which would allow quick data recording, storage and retrieval in a computer is recommended (Saad, et al, 1985).

MATERIALS AND METHODS

In many instances, scientists conducting on-farm research develop new terms and definitions to describe their work (Nordblom, et al., 1985; Pervaiz and Knipscheer, 1989). The high variability often observed in results of on-farm research and extra information obtained supports the results e.g. information from farmers, may justify the acceptance of low significance levels such as 10% or 20% confidence limits (Nordlom et al., 1985).

Lake Elementata to the west and the Kinangop plateau to the east.

The farms which were studied in Mai-Mahlu, Kambogo and Kiungu lie within about 40 to 70 km to the south and south-east of Naivasha town. Suswa and Mireia lie within about 40 km to the south and west of Naivasha town respectively. Another area was taken about 5 km north west of Naivasha town. This area is scarcely populated and the goats used for the study belonged to one farmer who grazed over a vast area of land.

In Gilgil division, two clusters were used for the study. One in Ngema Location consisted of farms which were within 7 km south-west of Gilgil town and the other at Kerancha within about 10 km to the north-west of Gilgil town bordering Lake Elementata to the west.

CHAPTER TWO

MATERIALS AND METHODS

2.1 The study area.

The area of study covered the Locations of Mai-Mahiu, Kiambugo, Kinungi, Suswa, and Mirela in Naivasha division. The area lies within the latitudes, $0^{\circ} 25'S$ and $1^{\circ} 00'S$ and the longitudes, $36^{\circ} 10'E$ and $36^{\circ} 30'E$ (centre co-ordinates $0^{\circ} 43'S$ and $36^{\circ} 25'E$). The study area is bordered by Mt. Longonot and Kijabe Hills to the south, Lake Naivasha and Lake Elementaita to the west and the Kinangop plateau to the east.

The farms which were studied in Mai-Mahiu, Kiambugo and Kinungi lie within about 40 to 70 km to the south and south-east of Naivasha town. Suswa and Mirela lie within about 40 km to the south and west of Naivasha town respectively. Another area was taken about 5 km north-west of Naivasha town. This area is scarcely populated and the goats used for the study belonged to one farmer who grazed over a vast area of land.

In Gilgil division, two clusters were used for the study. One in Ngema Location consisted of farms which were within 7 km south-west of Gilgil town and the other at Kariandusi within about 10 km to the north-west of Gilgil town bordering Lake Elementaita to the west.

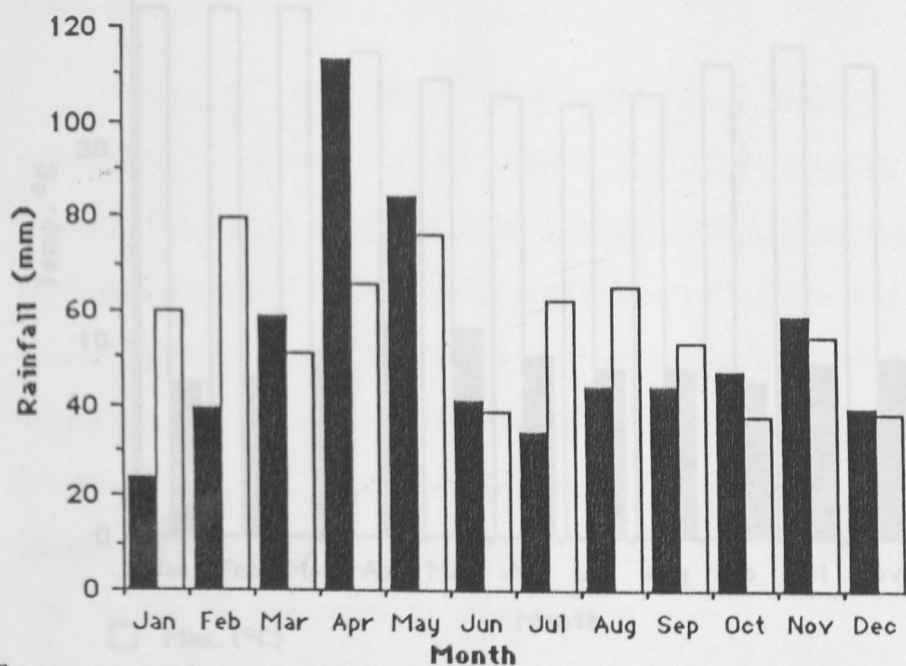
The areas were accessible by vehicle. The study was confined to one or two clusters in each location depending on the population of goats in the areas.

Physiography

The physiography of the study area is similar; generally flat with gently undulating plains. The height varies between 1,740 M at Mai-Mahiu to 2,140 M in most areas except Kinungi which is more elevated at 2,400-2,480 M.

The soils, as described by Siderius and Muchena (1977), are "Gamblian Lake" sediments mainly clayery with considerable amounts of silt, sodium salts and gravel. There is no significant variation of soil type recorded by soil analysts in this study area.

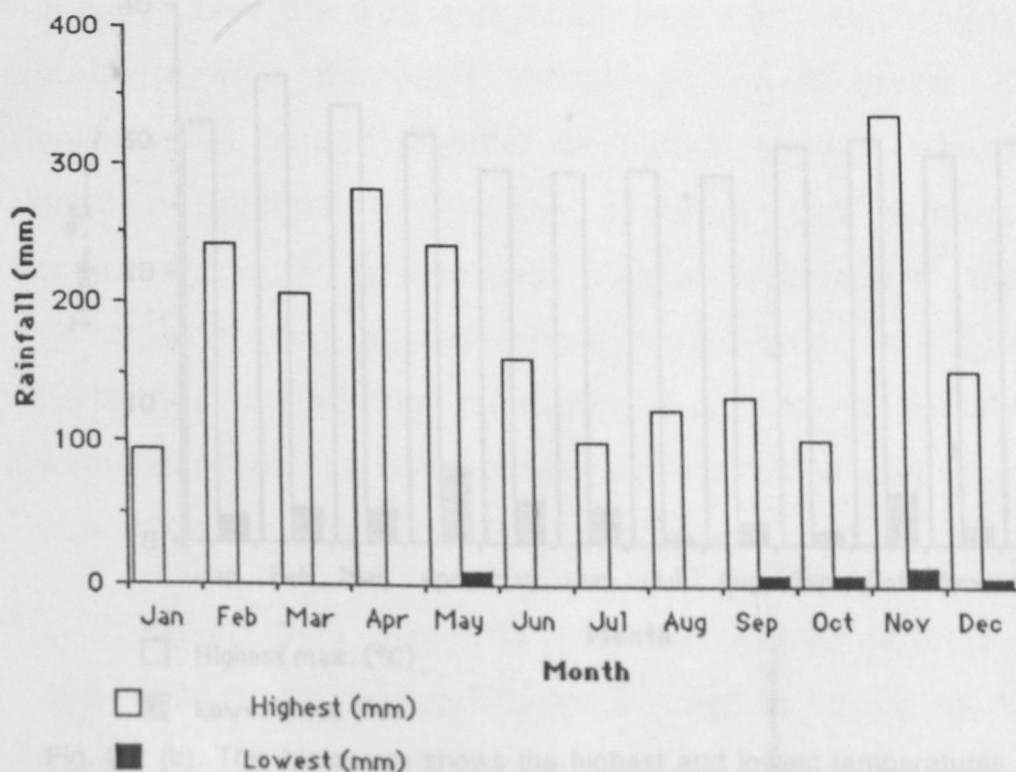
The area is generally semi-arid and is hot and dry with an annual maximum temperature of 35°C. The mean monthly maximum temperature is 27.5°C and the lowest temperature recorded is 0.6°C (Fig. 2.2 (a) &(b)), (Meteoroological department records, means for the years, 1910-1980 recorded at Naivasha water station. Data for the period of study was not available). Mean annual rainfall is 627 mm. Rainfall is poorly distributed and reliability is poor (Fig. 2.1 (a) &(b)). The area is characterised by two rainy seasons: long wet season which occurs between March and May and a short wet season which lasts from July to November.



■ mean monthly Rainfall (mm)

□ max. 24 hrs fall (mm)

Fig 2.1 (a). The mean monthly and maximum 24 hrs rainfall for the period 1910 to 1980. Data for period of study not available. Naivasha Water. Station No. 90.36/28 Latitude $00^{\circ} 44'S$, Longitude $36^{\circ} 27'E$, Altitude 1936 metres.



□ Highest (mm)

■ Lowest (mm)

Fig. 2.1 (b). The lowest and highest monthly rainfall for the period 1910 to 1980. Data for period of study not available. Naivasha Water Station No. 90.36/281. Latitude $00^{\circ} 44'S$, Longitude $36^{\circ} 27'E$, Altitude 1936 metres.

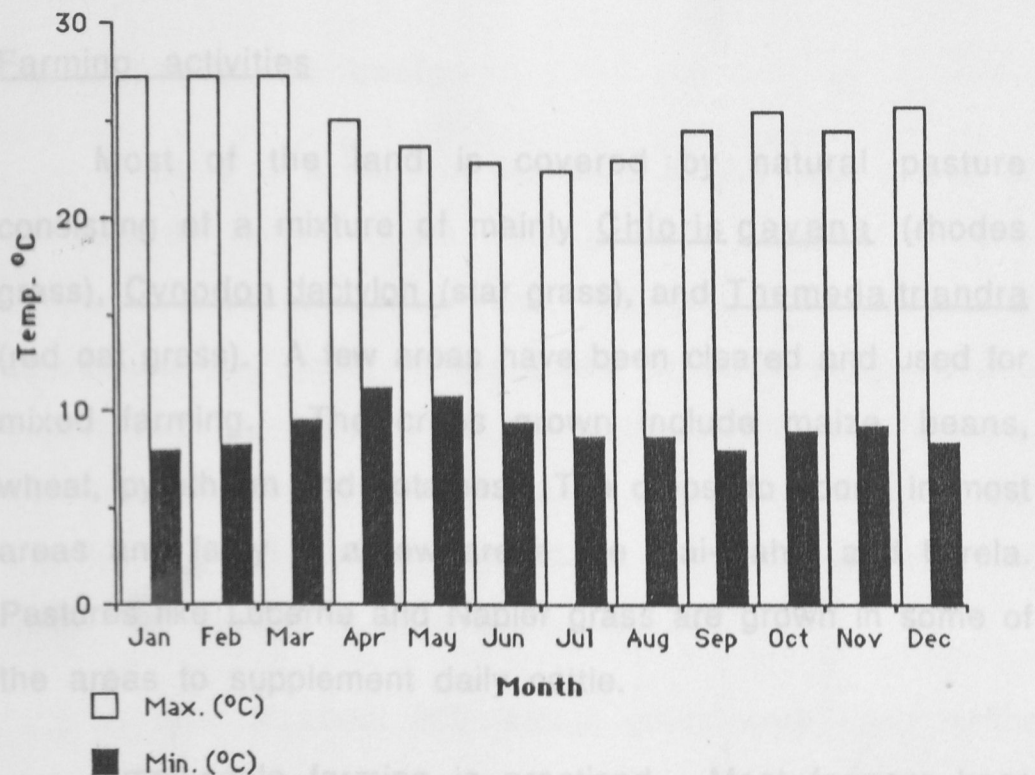


Fig. 2.2 (a) Mean monthly maximum and minimum temperatures for the period 1937 to 1980. Data for period of study not available. Naivasha Water Station No. 90.36/281. Latitude $00^{\circ} 44'S$, Longitude $36^{\circ} 27'E$, Altitude 1936 metres.

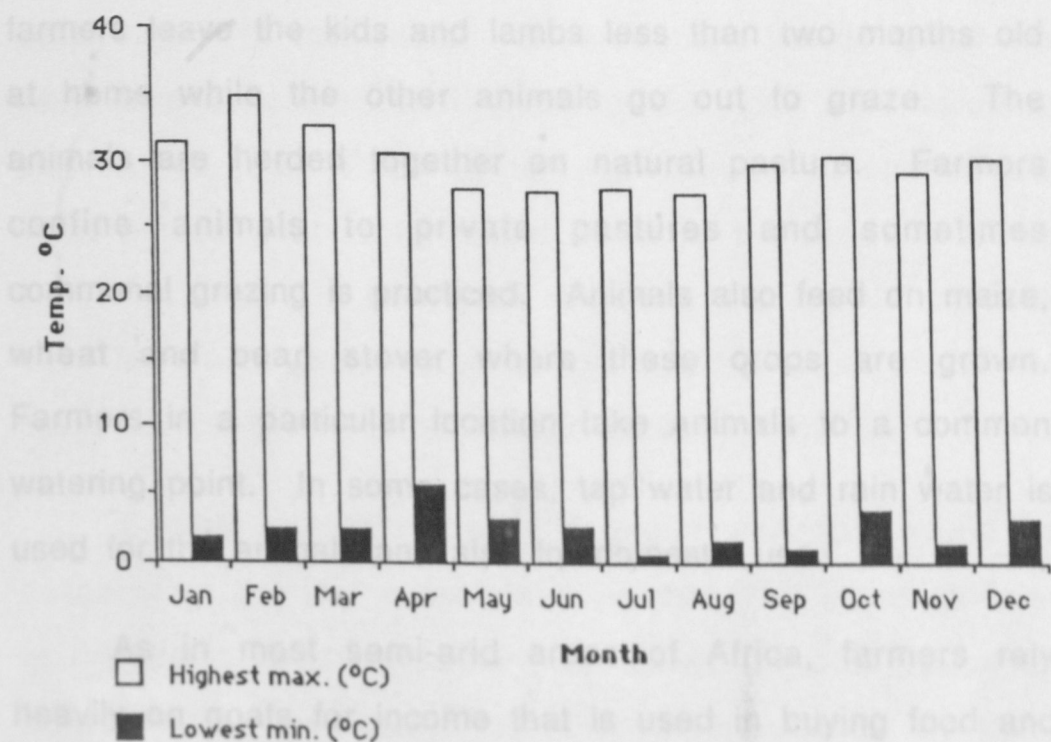


Fig. 2.2 (b). This histogram shows the highest and lowest temperatures observed in the respective months of the year for the period 1937 to 1980, (data for period of study not available). Naivasha Water Station No. 90.36/281. Latitude $00^{\circ} 44'S$, Longitude $36^{\circ} 27'E$, Altitude 1936 metres.

Farming activities

Most of the land is covered by natural pasture consisting of a mixture of mainly Chloris gayana (rhodes grass), Cynodon dactylon (star grass), and Themeda triandra (red oat grass). A few areas have been cleared and used for mixed farming. The crops grown include maize, beans, wheat, pyrethrum and potatoes. The crops do poorly in most areas and fairly in a few areas like Mai-Mahiu and Mirela. Pastures like Lucerne and Napier grass are grown in some of the areas to supplement daily cattle.

Small-scale farming is practiced. Most farmers keep goats mainly of the small East African breed. Some keep goats together with sheep and a few keep cattle. Most farmers leave the kids and lambs less than two months old at home while the other animals go out to graze. The animals are herded together on natural pasture. Farmers confine animals to private pastures and sometimes communal grazing is practiced. Animals also feed on maize, wheat and bean stover where these crops are grown. Farmers in a particular location take animals to a common watering point. In some cases, tap water and rain water is used for the animals and also for domestic use.

As in most semi-arid areas of Africa, farmers rely heavily on goats for income that is used in buying food and as an important source of meat. Most farmers rely on cattle for milk and occasionally for meat and revenue.

2.2 Experimental design

A group of farmers in the same locality with a total of at least 80 female goats were grouped together as one cluster. Accessibility by road, willingness of farmers to co-operate, availability of the goats for blood sampling and examination contributed to the selection of the farmers. Ten clusters were sited in the area, one or two clusters per administrative Location depending on the population of goats and farmers in a particular Location.

A total of about 800 female goats were used in the study. A questionnaire was prepared (see appendix) and was completed during the study for determination of management practices and estimation of reproductive performance of the goats. Several adult female goats on each farm depending on the size of the flock were selected and ear tagged. Each farmer was allowed to choose the adult female goats they would allow to be used for blood sampling. Four to five adult female goats were chosen in each farm and sixteen adult female goats in each cluster for blood sampling and determination of body condition.

It was intended that 160 blood samples would be collected in the dry season and another 160 blood samples in the wet season. However, some farmers sold out a few goats during the study and there were losses of some experimental goats during the period of study.

At the end of the survey, 135 blood samples from dry season and 147 from wet season were available for serum Vit. B₁₂ analysis and hematology giving a total of 282 blood samples. The same number of goats were examined for body condition.

2.4 Blood Analyses

The dry season extended from mid October 1990 to February 1991. The wet season data collection was done during the short wet season from August to October 1991.

Data collection and blood sampling were performed by visiting four or five farms per day in a week. The survey was conducted over 4 and 1/2 months during the dry season and another 2 and 1/2 months during the wet season.

2.3 Collection of Blood Samples

Blood samples were obtained by jugular venipuncture. 4 to 5 ml of blood was collected into universal bottles and allowed to stand and clot at an angle of about 45° in a cooler box at 4-8°C.

Serum was then decanted into sterile tubes and transported to the laboratory in the cooler box (4-8°C) after which the samples were stored in a deep freezer set at -20°C for subsequent Vit. B₁₂ analysis.

Another 2 mls of whole blood was collected directly into tubes containing the anticoagulant, heparin for haematology.

A drop of whole blood was used for on-the-spot determination of glucose concentration using a glucometer® (Ames Glucometer® II).

2.4 Blood Analyses

2.4.1 Vitamin B₁₂ assay

The concentration of serum Vitamin B₁₂ was determined by radioisotopic competitive inhibition method for Vit. B₁₂ ⁵⁷Co. Commercially available Vit. B₁₂/Folate dual radioassay kits were purchased from Amersham International Laboratories. This method is a modification of the original radioassay method (Millar and Penrose, 1980), in which boiling at 95°C is replaced by use of denaturation reagent (Amersham Labs.) at room temperature. The details of the procedure used is described below.

Procedure of Radioassay

In this assay, serum Vit. B₁₂ competes with ⁵⁷Co-labelled Vit. B₁₂ for sites on purified intrinsic factor which is the binding protein. The standards and unknowns were assayed together in duplicate.

Using precision pipettes, 200 µl aliquotes of standards and sample were transferred to the bottom of

polystyrene assay tubes and mixed with 100 μ l of ^{57}Co -labeled Vit. B₁₂ solution followed by 100 μ l denaturation reagent (Amersham Labs.). The mixture was vortex mixed and incubated at room temperature, (18-28°C) for 15 minutes to free Vit. B₁₂ from the binding proteins. This process occurs at pH 12.8-13.0 and irreversibly denatures the binding proteins thereby releasing Vit. B₁₂ from serum binding proteins.

To each tube was then added 1000 μ l of binding protein. After vortex mixing, the mixture was incubated at room temperature (18-28°C) for 45 minutes for one hour. The amount of ^{57}Co -labeled Vit. B₁₂ that binds to the intrinsic factor is inversely proportional to the serum Vit. B₁₂ concentration in the reacting medium.

Following incubation, a charcoal tablet was added into each tube, allowed to disintegrate for 5-10 seconds and then the mixture vortex mixed. The tubes were incubated at room temperature for 15 minutes. This allowed separation of the protein bound Vit. B₁₂ from the free fraction as the free fraction was adsorbed on coated charcoal.

The tubes were centrifuged at 1500 g for 15 minutes. The supernatant liquid was decanted into a clean set of assay tubes and counted using a gamma counter (Nuclear Enterprises NE 1600) set to count ^{57}Co .

The concentration of Vit. B₁₂ in unknown sample was determined using the equation derived from the standard curve (Fig 2.3).

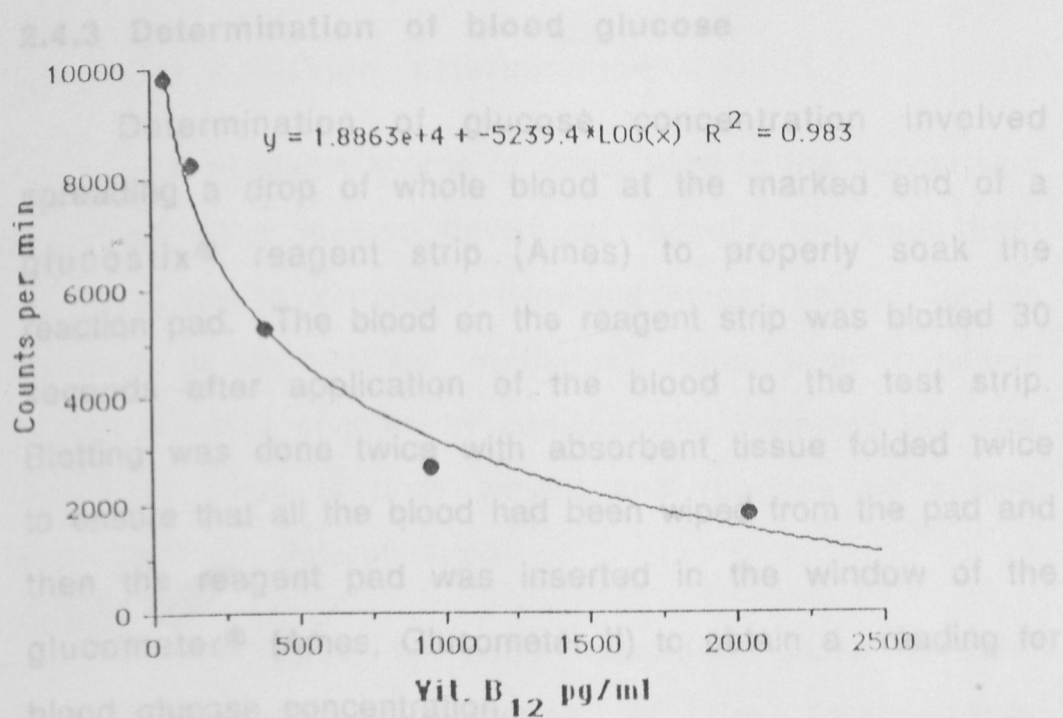


Fig. 2.3. Standard curve for Vit. B₁₂ determination

2.4.2 Haematology

Packed cell volume % was determined by centrifuging blood in microcapillary tubes using a micro-centrifuge for 5 minutes and reading the PCV% of whole blood on a haematocrit scale. RBC count, WBC count and MCV were determined using a coulter counter (Coulter electronics Inc., Hialeah, Florida). Haemoglobin was determined by a Haemoglobinometer (coultronics, France S.A 95580) after lysing red blood cells with Zap-oglobin® (Coulter electronics) which is a solution containing potassium cyanide.

2.4.3 Determination of blood glucose

Determination of glucose concentration involved spreading a drop of whole blood at the marked end of a glucostix® reagent strip (Ames) to properly soak the reaction pad. The blood on the reagent strip was blotted 30 seconds after application of the blood to the test strip. Blotting was done twice with absorbent tissue folded twice to ensure that all the blood had been wiped from the pad and then the reagent pad was inserted in the window of the glucometer® (Ames, Glucometer II) to obtain a reading for blood glucose concentration.

The glucostix® reagent strips contain 0.6 i.u. glucose oxidase, 6.0 i.u. peroxidase, 75 µg ortho-tolidine, and 91% w/w non reactive ingredients (Ames). The reaction is based on the action of glucose oxidase enzyme which catalyses the oxidation of glucose in blood by oxygen from the atmosphere, producing gluculonic acid and hydrogen peroxide. In the presence of peroxidase, the ortho-tolidine is oxidised by hydrogen peroxide producing a shade of green colour intensity proportional to the glucose concentration.

The glucometer® measures the amount of light reflected from the reacted test pad electronically. A direct reading of the glucose concentration in mg per 100 ml of blood is displayed on the digital display screen.

2.5 Body condition determination

Body condition scores of goats used in the survey was accessed by a method developed recently for small East African goats in Zimbabwe (Honhold et al., 1987). As an estimate of an animals' nutritional status body condition scores are less affected by compounding variables like age, sex, e.t.c. than is body weight and requires no special equipment for determination.

Determination of body condition score involved determining the prominence of the intervertebral articulations which were felt as hard round protuberances at the angle between the vertical and horizontal processes in thinner goats. The amount of muscle cover on the vertebrae, the extent to which the muscle extends above and along the horizontal process was estimated. The prominence of the ends of the transverse processes, the shape of the tissue boundary between the transverse processes and the shape of the muscle cover between the spinous and transverse processes (whether concave or convex) were also determined. All these were determined at the lumbar vertebrae region with the thumb on one side and the four fingers on the other side of the spinous processes. Deep palpation was carried out to feel for bone prominences and the depth of the muscle cover. The four fingers were inserted between the borders of the transverse processes to determine the shape of the muscle in the interspinous space.

By moving the hand along the lumbar region both cranially and caudally, these factors were determined and combined to give the body condition score as described by Honhold et al. (1987). Each goat was assigned a score ranging from 1.0 to 4.0. Two independent people assessed the score for each goat and the average of their findings was taken to represent the body condition score of a particular goat. To minimise subjective differences, the same two people did the scoring throughout the study.

2.6 Estimation of Reproductive performance

Estimation of reproductive performance was done by a method modified from the method used by Musewe and Gombe (1980) for estimation of reproductive performance in cattle combined with the method used by Njanja (1988) in evaluation of productivity in small stock and camels under Turkana pastoral production system.

Reproductive rates were determined in goats in every herd through a questionnaire (Appendix, part II) and by examining the herd structure twice during the period of study. Every farmer was visited twice at an interval of 11 to 12 months in the years 1990 and 1991.

It was established that there are two kidding seasons per year for goats in the area of study. The first season in the period March to April and the second season in August to September, though there were also a few kiddings in the remaining months of the year. The small East African goat

in the area was found to attain puberty at 7-9 months instead of the expected 6 months (Skea, 1988).

During the farm visits, the herd structure of every herd was recorded as shown in the questionnaire (Appendix, part II).

The number of animals (M+F) found to be below puberty and above 3 months of age in the dry season visits of October 1990 to February 1991 was taken to be the number of weaners from the first kidding season March/April 1990. The number of kids born in the second kidding season (August/September) were determined by the number of kids found less than 2-3 months of age at the time of the interviews in August to October 1991. This method is adopted from findings by (Njanja 1988) and Musewe and Gombe (1980).

The number of adult females was recorded and information regarding which ones had kidded and the pregnant ones at the time of data collection was obtained. Information regarding abortions or miscarriages was also recorded.

The components of reproductive performance were calculated as adopted from definitions of fertility in sheep factors by Carles (1983) as follows:

- (a) Number of does kidding per doe mated (Conception rate)
- (b) Number of kids born per doe kidding (Average litter size)
- (c) Number of kids born per doe mated (combination of (a) and (b)). This was taken to be the reproductive rate
- (d) Number weaned per kids born (Survival rate from birth to weaning)

These rates were expressed as percentages. The weaning rate as a percentage was then calculated by combining (a), (b) and (d) above to give the kids weaned per does mated, given by $(a) \times (b) \times (d)$ (Carles, 1983). Both the weaning and the reproductive rates were then expressed per 12 months.

These rates were calculated for each herd separately and by combining data for dry and wet season, the average reproductive rate per doe per year and the weaning rate (weaners per kids born per year) was calculated. The average for each cluster was obtained by combining the results for all the farms in the cluster.

2.7 Management practices

Management practices were also determined through the questionnaire (see Appendix). The type of farming system, other animals kept in the farm, sources of feed and water for the animals, the size of grazing areas were recorded. In addition, supplementation with mineral preparations, their sources and frequency as well as methods of application were noted. The farmers were asked whether they fed any concentrates to the goats.

To assess the herd health status, information regarding endemic diseases in the area during the period of study, disease control practices, the type of anthelmintics used and the frequency of application was investigated. Some of the fairly educated farmers gave information

regarding these aspects of management and disease control practices, some showed samples of the mineral supplements and some of the anthelmintics. Local veterinarians and animal health assistants also gave information about the endemic diseases and disease control practices in the area of study and even in specific farms. Additional information consisted of observations which were made in the farms during the study.

All this information helped to allocate the farmers' management practices into four groups; Farmers who practiced free grazing of the goats and other livestock and had little or nothing to do with crop farming were grouped together as pastoralists. This group of farmers mostly had big flocks of goats from 100 to >400. Those who practiced crop farming and reared a few goats mostly less than 30, and confined the goats to private farm and the homestead were grouped together as mixed farmers. The goats from farms where mineral supplementation was practiced, were grouped together as mineral supplemented (S) and goats from farms where no mineral supplements were given as non-supplemented (NS) goats. It was observed that farmers in the same locality practiced similar livestock managements.

The mineral supplements that were considered in the mineral supplemented goats contained cobalt as derived from the questionnaire. The mineral supplement Afya Bora® Ready Block by Unga feeds Ltd. according to the manufacturers, contained 9 mg Co/kg at a recommended

daily intake of 25 gm/100 kg live weight for all animals was frequently used on the goats. The other mineral supplement used commonly was Baymix® Lamba mineral Block (Bayer and Bayer Ltd.) and contained a similar elemental composition to the Ready® block (Unga feeds Ltd.) and was recommended for all animals.

Some farmers used Maclik Supper® (KBS 4) TAL L0083 manufactured by Cooper Kenya Ltd., Twiga chemical industries Ltd. which contained 0.02% cobalt according to the manufacturers. This is recommended for daily cattle but some farmers used it for goats. There was another mineral preparation by Unga feeds Ltd., Afya Bora® Supper lick containing 0.0014% cobalt and recommended for daily cattle by the manufacturers but some farmers used it for goats.

A few farmers used Co-incorporated anthelmintics on the goats. The Co-incorporated anthelmintic, Nilzan Plus® by Cooper TAL L0216 which contained 0.382% cobalt sulphate (Cooper, Kenya) was given to the goats by a few farmers every three months for helminth control. Some farmers took 6 months and 1 year between anthelmintic treatments and it is likely that the component of Co from this source was not beneficial to the goats. Such goats were not included in the mineral supplemented group.

2.8 Statistical Analysis

Each of the parameters, serum Vit. B₁₂ levels, blood glucose, haematology parameters and body condition scores, were determined and compared for each of the contrasting groups of managements, season, and between one cluster and another. These parameters were measured for adult female goats and therefore differences arising from age, sex, and body weight especially for body condition scores were not expected.

Statistical analysis was carried out by the analysis of difference of means using the Students' unpaired t-test according to Steel and Torrie (1987). The levels of significance were taken at 95% ($P < 0.05$). Results are presented as mean $\pm$ standard error of mean (S.E.M).

Percentage distribution curves were determined for each parameter and the numbers of the goats falling in each of the regions; within normal and below ranges for goats were determined. The numbers of goats that had levels in the normal range but below the required average were also studied. The nature of sample distribution curves and the areas under the curve which represented the fraction of goats within a particular region was compared for the contrasting groups of goats under contrasting managements and season.

CHAPTER THREE

RESULTS AND DISCUSSION

3.1 Levels of Serum Vitamin B₁₂

The goats were found to have serum Vit. B₁₂ levels ranging from a minimum of 20.2 pg/ml to a maximum of 937.5 pg/ml. Based on sheep production reference ranges (Clark et al., 1984), the mean serum Vit. B₁₂, 205.5±9.37 pg/ml was below 370 pg/ml that is considered to be the lowest adequate serum Vit. B₁₂ concentration in normal sheep. Only 22 out of 218, i.e. 10.1%, of the animals had serum Vit. B₁₂ levels above 370 pg/ml and were cobalt adequate (Fig. 3.1).

Among the goats analysed for serum Vit. B₁₂, 196, or 89.5% had serum Vit. B₁₂ levels below 370 pg/ml. Of these 122 representing 56.4% of the female goats had serum Vit. B₁₂ levels less than 180 pg/ml and were thus Vit. B₁₂ deficient based on sheep production reference ranges (Clark et al., 1984). The remaining 74 (33.5%) goats had Vit. B₁₂ levels in the marginal Co deficiency range i.e., 180-370 pg/ml for sheep (Fig. 3.1).

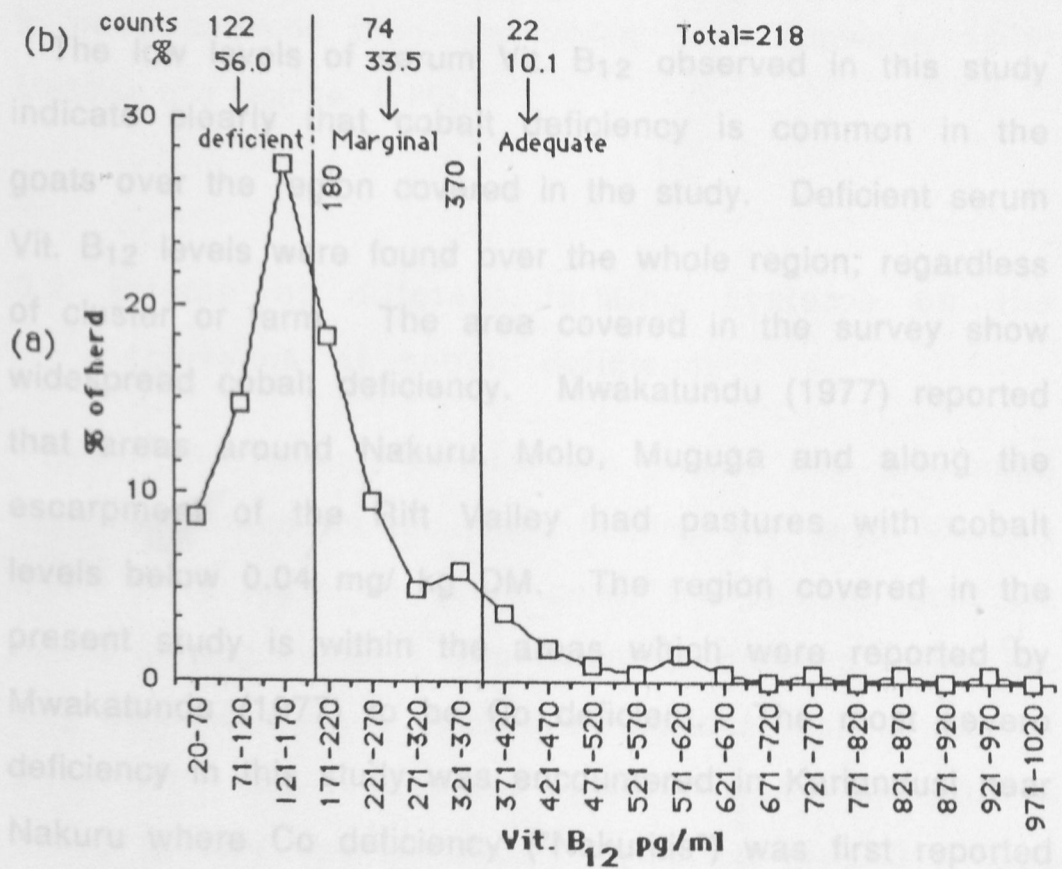


Fig. 3.1: Serum Vit. B₁₂ concentration (pg/ml) of 218 goats encountered in the survey.

Part (a). Percentage distribution of serum Vit. B₁₂ levels in the goats. Each point represents the percentage of the goats with serum Vit. B₁₂ levels in the corresponding range. The vertical lines mark the deficiency (<180 pg/ml), marginal deficiency (180-370 pg/ml) and adequacy (>370 pg/ml) ranges described in sheep (Clark et al., 1984).

Part (b). The numbers and fractions as a percentage of the goats with serum Vit. B₁₂ levels in the corresponding ranges. The fractions are represented by the area under the curve within the range limits.

The low levels of serum Vit. B₁₂ observed in this study indicate clearly that cobalt deficiency is common in the goats over the region covered in the study. Deficient serum Vit. B₁₂ levels were found over the whole region; regardless of cluster or farm. The area covered in the survey show widespread cobalt deficiency. Mwakatundu (1977) reported that areas around Nakuru, Molo, Muguga and along the escarpment of the Rift Valley had pastures with cobalt levels below 0.04 mg/ kg DM. The region covered in the present study is within the areas which were reported by Mwakatundu (1977) to be Co deficient. The most severe deficiency in this study was encountered in Kariandusi near Nakuru where Co deficiency ("Nakuritis") was first reported in East Africa (Howard, 1963, 1969).

Under laboratory conditions, feeding goats with Co deficient hay from this areas has confirmed the occurrence of the deficiency (Mgongo et al., 1984; Gombe and Verjee, 1976; Mburu, 1991). Occurrence of Co deficiency in cattle grazing in these areas have been reported in the past (Musewe and Gombe, 1980). The present study confirms that goats grazing pastures in these areas develop Co deficiency and lends support to the laboratory findings of Co deficiency when goats are fed on hay from the area.

A high proportion of goats showed a serum Vit. B₁₂ concentration in the range 185-370 pg/ml which is indicative of marginal deficiency (Clark et al., 1984). This is in support of earlier reports that marginal Co deficiency

is more common than the clinical form (Howard, 1969; Musewe and Gombe, 1980).

parameter	pastoralism	mixed
Vit. B ₁₂	231±13.75	168.6±10.43
pg/ml		

3.2 Effects of different farming systems on the occurrence of cobalt deficiency

When the farming systems are divided into two broad systems; pastoralism and mixed farming, the serum Vit. B₁₂ levels were higher in goats under the pastoral than the mixed farming system. The difference between serum Vit. B₁₂ concentrations in goats reared under pastoral system, 231±13.75 and 168.6±10.43 pg/ml for goats belonging to mixed farmers was statistically significant (p<0.001; Table 3.1).

serum	2.7±0.05 *	2.5±0.08
Blood glucose	4.0±0.03	3.9±0.9
x10 ³ mg/100 ml		

Key:
* -Statistically significant at 95%,
** -Statistically significant at 99%.

Table 3.1: Serum Vit. B₁₂ concentrations, body condition scores and other blood parameters in goats under pastoral and mixed farming systems.

parameter	pastoralism	mixed
Vit. B ₁₂ pg/ml	231±13.75 **	168.6±10.43
Hb gm/100 ml	9.00±8.4 *	8.4±0.21
RBC x10 ⁶ /mm ³	12.6±0.25	12.7±0.32
PCV%	23.72±0.31	24.48±0.58
MCV cu.μ	20.5±0.19	20.81±0.29
WBC x10 ³ /mm ³	11.9±0.32	12.4±0.37
Bo. co. sco.	2.7±0.05 *	2.5±0.06
Blood glucose x10 mg/100 ml	4.0±0.09	3.9±0.9

Key:

* -Statistically significant at 95%,

** -Statistically significant at 99%.

The higher serum Vit. B₁₂ levels obtained for goats in the pastoral than the mixed farming systems suggests that goats reared under the pastoral system enjoyed better management than goats reared under mixed farming system. Mineral supplementation that was more prevalent in these group of farmers compared to the mixed farmers helped to reduce the incidence of the occurrence of Co deficiency in goats in this study. Also, free grazing allowed animals to have a wider range of herbage selection which probably assisted in avoiding the occurrence of Co deficiency (Underwood, 1981; Mills, 1981). Different plant species and parts are known to contain varying amounts of cobalt and it is possible that the goats selected the plants or parts of plants richer in cobalt. The goats reared under mixed farming system were confined to private farms and were not allowed wide grazing areas, and thus had less access to pasture selection and were more predisposed to Co deficiency compared to goats reared under pastoralist system.

In most part of the year, the region covered was found to be dry and the grass was less than 7-10 cm tall. The occurrence of short pastures allows animals to ingest soil during grazing which provides a significant source of cobalt to grazing animals (Underwood, 1981; Mason and Mackay, 1983; Scheidner et al., 1991). Scheidner et al. (1991), has described clinical Co deficiency in sheep grazing pastures in south-western Cape province which occurred in the spring season when pastures are good in quality and quantity and

was not found to occur in the autumn season when the pastures were dry and poor in quality and soil ingestion helped to avoid the deficiency. In the present study, soil Co was an additional factor in lessening the incidence of Co deficiency in goats reared under pastoral farming system which allows soil ingestion during grazing compared to goats under mixed farming system which were not allowed a wide accessibility to free grazing.

During the visits to the farms, it was noticed that most of the pastoralists were comparatively well to do. They had large herds of goats (over 100 goats in addition to large flocks of sheep and a few head of cattle. Most of the pastoralists treated the animals for helminths at three month intervals. Some treated the animals with Co-incorporated anthelmintic and offered mineral supplement containing cobalt; some fed concentrates to nursing does and ewes. The cobalt contents of concentrates is generally higher than that of pasture (Underwood, 1981). Thus, goats reared under this system were better managed and therefore not as prone to deficiency as those in the mixed farms. Musewe and Gombe (1980) found that cattle in poorly managed farms in Co deficient areas are more likely to slip into deficiency compared to those in well managed farms.

3.3 Effects of mineral supplementation on the occurrence of cobalt deficiency

The mean serum Vit. B₁₂ levels of the goats that received mineral supplementation, (S group) was 385.9 ± 26.16 pg/ml. This level was significantly higher ($P < 0.001$) than 136.2 ± 8.59 pg/ml for goats that were not mineral supplemented, (NS group) (Table 3.2).

Among the S group, 12 out of 24 i.e 50% of the goats, were marginally deficient as their serum Vit. B₁₂ concentrations fell in the range 180-370 pg/ml. The other 12 goats (50%) had adequate levels of serum Vit. B₁₂ (above 370 pg/ml). All the goats that were supplemented with minerals had serum Vit. B₁₂ levels above the deficiency level of 180 pg/ml (Fig. 3.2).

The goats that did not receive mineral supplementation were clearly deficient; 22 out of 24 (91.7%) goats in this group had Vit. B₁₂ levels below 180 pg/ml. Only 2 (8.3%) goats in this group had serum Vit. B₁₂ levels in the range of 180-370 pg/ml and none of them was found to have serum Vit. B₁₂ levels in the adequate range (Fig. 3.2).

Table 3.2: Serum Vit. B₁₂, body condition scores and some blood parameters in mineral supplemented (S) and non-supplemented (NS) goats.

parameter	S group	NS group
Vit. B ₁₂ pg/ml	385.9±26.16 **	136.2±8.59
Hb gm/100 ml	8.23±0.41	9.62±0.37 *
PCV %	22.04±0.53	25.61±0.92 **
MCV cu.μ	21.83±0.36 *	20.63±0.36
RBC x10 ⁶ /mm ³	10.4±0.31	13.85±0.68 **
WBC x10 ³ /mm ³	11.0±0.63	10.7±0.53
Bo. co. sco.	2.73±0.1	2.48±0.12

Key:

- * -Statistically significant at 95%
- ** -Statistically significant at 99%.

Part (b). The numbers and fractions as a percentage of goats with serum Vit. B₁₂ levels in the corresponding ranges.

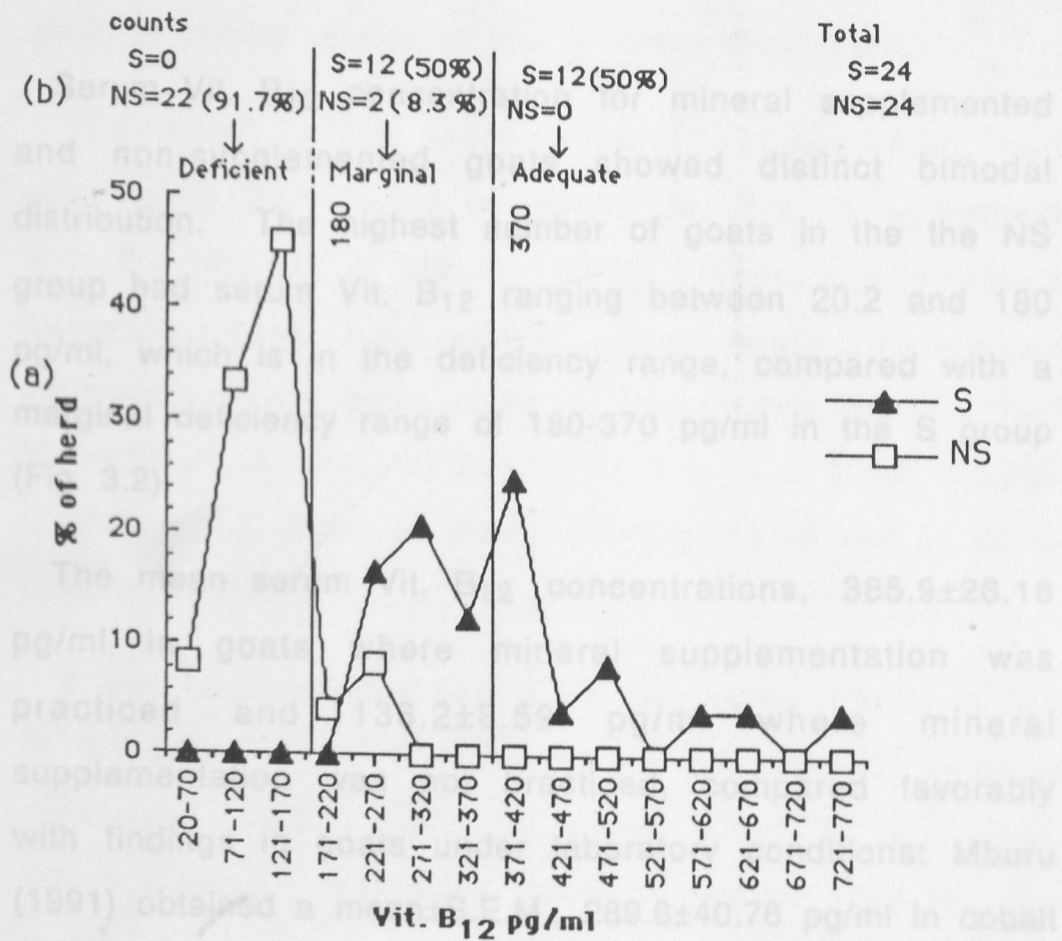


Fig. 3.2: Part (a). Percentage distribution of serum Vit. B₁₂ levels in the S and NS goats. The lines mark the deficiency, marginal and adequacy serum Vit B₁₂ ranges based on levels in sheep.

Part (b). The numbers and fractions as a percentage of goats with serum Vit. B₁₂ levels in the corresponding ranges.

goats is closely related to that of cattle than sheep.

Serum Vit. B₁₂ concentration for mineral supplemented and non-supplemented goats showed distinct bimodal distribution. The highest number of goats in the the NS group had serum Vit. B₁₂ ranging between 20.2 and 180 pg/ml, which is in the deficiency range, compared with a marginal deficiency range of 180-370 pg/ml in the S group (Fig. 3.2).

The mean serum Vit. B₁₂ concentrations, 385.9 ± 26.16 pg/ml in goats where mineral supplementation was practiced and 136.2 ± 8.59 pg/ml where mineral supplementation was not practiced, compared favorably with findings in goats under laboratory conditions: Mburu (1991) obtained a mean $\pm$ S.E.M., 289.6 ± 40.76 pg/ml in cobalt supplemented goats compared to 142.8 ± 28.27 pg/ml in Co deficient controls fed on hay from Nakuru.

In the present study, the serum Vit. B₁₂ levels in unsupplemented goats was below 200-250 pg/ml which is considered to be the lower critical level for sheep (Underwood, 1977; Tressol and Lamand, 1979; Rice et al., 1987). The finding that the deficient goats had serum Vit. B₁₂ concentrations below 200 pg/ml indicates that the requirement of Co/Vit. B₁₂ for goats may be slightly below that of sheep as suggested by Mburu (1991). Cobalt requirements for cattle are lower than for sheep (Underwood, 1981). The findings of the present and previous studies (Mgongo et al., 1981; Clark et al., 1987; Mburu, 1991) show that the serum Vit. B₁₂ reference range for

goats is closely related to that of cattle than sheep.

The goats which were mineral supplemented had consistently high levels of serum Vit. B₁₂ in agreement with the findings of Mburu (1991). When supplementary minerals were not offered, the goats maintained comparatively low levels of serum B₁₂. It has been reported in previous studies that serum Vit. B₁₂ is a good indicator of dietary Co intake in sheep (Findlay, 1972) and in goats (Mburu, 1991).

It was observed that serum Vit. B₁₂ concentration in half of the goats in the S group fell in the range of marginal deficiency 180-370 pg/ml for sheep (Clark et al., 1984). When stressed, marginally deficient animals may fall into overt deficiency; for example, helminth infestation predisposes animals already in marginal Co deficiency to clinical deficiency (Downey, 1966). Nutritional stress such as energy deprivation reduces the benefits of increased dietary cobalt after supplementation in cattle (Howard, 1970 cited by Roeder, 1980).

The areas covered in this study are known to be both cobalt and copper deficient (Howard, 1963). This region is characterized by a semi-arid climate and thus inadequate dietary energy intake is a major problem to the animals. From the questionnaire, it was clear that disease control was often absent or poor, no vaccinations for contagious caprine pluropneumonia (which is endemic in this area) was practiced and anthelmintic treatment was rare especially in

the mixed farms. The above stress factors are likely to contribute to development of clinical in marginally deficient goats.

It is evident that the two mineral preparations Afya Bora® Ready Block by Unga feeds Ltd. and Baymix® Lamba mineral Block by Bayer and Bayer which contain 9 mg Co/Kg could supply sufficient Co to goats if given at the optimum rate of 25 mg/kg body weight advised by the manufacturers. The mineral preparations, Maclick Super® (KBS 4, Cooper Kenya Ltd.) and Afya Bora® Super lick (Unga feeds) containing 0.02% and 0.0014% cobalt respectively, might require large proportions of the supplement to meet the requirement levels for goats.

The case demonstrated by the S group is one of marginal deficiency occurring when goats are supplemented in practical farm management situations. Only 50% mineral supplemented goats had serum B₁₂ levels in the adequate region (>370 pg/ml). There are reports that Co deficiency was cured by feeding minute amounts of Co contained in lamonite in southern Australia (Underwood and Filmer, 1935). Thus the occurrence of marginal deficiency in mineral supplemented goats in the present study could be explained by inefficient methods of administration of the supplement.

The results indicate that it is likely for some goats within the flock to slip into deficiency even when the flock is supplemented with cobalt containing mineral

supplements in endemic areas of cobalt deficiency. This is in agreement with earlier findings in cattle grazing in these areas (Musewe and Gombe, 1980).

Many of the farmers interviewed said they offered the granular form of the supplements to all the goats in common troughs. The strong ones were therefore likely to get enough at the expense of the weaker ones. Some farmers gave the supplements as solid blocks and animals were allowed to lick freely. These methods allowed competition with the strong animals being likely to lick enough at the expense of the weaker ones. Also, licking was found to be relatively slow, and goats can take relatively long to lick enough of the active ingredient from the solid block. Other farmers could have underestimated the amounts offered which lead to innadequate supplementation levels for the goats.

These results study suggest that only under very strict management conditions with regular supplementation ensuring that all goats get adequate amounts of the trace element regularly can the condition be prevented effectively. The observation that none of the goats analysed in the mineral supplemented group had serum Vit. B₁₂ levels in the deficiency range shows that if the animals are supplemented adequately the deficiency can be prevented in goats.

The results of this survey indicate that goats left to rely only on the cobalt supplies from pastures and farm crops in

cobalt deficient areas develop Vit. B₁₂ deficiency. Most of the farmers in the NS group were practising both crop farming and livestock rearing and had fewer goats and sheep compared to farmers who kept goats on free range who had larger flocks but little crop farming. The mixed farmers took livestock rearing secondary to crop farming and attached little or no importance to buying mineral supplements for the animals. The farmers were either ignorant of the importance of mineral supplementation or the salts were unaffordable to them.

3.4 Role of season in the occurrence of Cobalt deficiency in goats

When the levels of serum Vit. B₁₂ in goats were compared between the two seasons, the levels in the wet season (271.4 ± 30.52 pg/ml) were much higher than the levels for the dry season 161.9 ± 9.93 pg/ml ($P < 0.001$; Table 3.3).

Table 3.3: Serum Vit. B₁₂ concentrations, body condition scores and blood parameters during the wet and the dry seasons.

parameter	dry season	wet season
serum Vit. B ₁₂ pg/ml	161.9±9.93	271.4±30.52 **
Hb gm/100 ml	8.8±0.17	8.7±0.18
RBCx10 ⁶ /mm ³	13.1±0.25 *	12.1±0.31
PCV%	23.9±0.4	24.2±0.42
MCV cu.μ	20.5±0.23	20.7±0.23
WBCx10 ³ /mm ³	13.2±0.35 **	10.9±0.29
Bo. co. sco	2.7±0.06 *	2.5±0.05
Blood. glucose x10 mg/100 ml	4.3±0.06	3.8±0.2

Key:

* -Statistically significant at 95%

** -Statistically significant at 99%.

The higher serum Vit. B₁₂ levels obtained in the wet season than the dry season is supported by earlier reports. Increased soil water content increases cobalt uptake by plants and therefore availability in the pastures (Underwood, 1981). The region of study is dominated mostly by clay soil (Siderius and Muchena, 1977) which has a high water-holding capacity. It is therefore not surprising that goats seem to take up more pasture Co in the wet season than the dry season.

3.5 Body condition in cobalt deficient goats

The body condition scores obtained are shown in Fig. 3.3. Out of 275 goats examined, 80 (or 29.1%) had body scores less than 2.0 - the lower limit recommended for breeding females in the East African goat (Skea, 1988). The rest 157 or 57.1% female goats had body condition scores ranging between 2.0 and 3.0 which is recommended for breeding females (Skea, 1988) while 38 or 14.0% had score above 4.0.

The mean body score for mineral supplemented was higher than for non-supplemented goats (mean $\pm$ S.E.M. 2.7 $\pm$ 0.05 and 2.5 $\pm$ 0.12) respectively (Table 3.2). The difference was not statistically significant, ($p>0.05$).

Body condition scores were significantly ($p<0.05$; Table 3.4) higher in the dry than wet season. The mean scores was 2.7 $\pm$ 0.06 and 2.5 $\pm$ 0.05) in the two seasons respectively.

The scores were higher in goats reared under the pastoral than the mixed farming systems (mean±S.E.M. 2.7 ± 0.05 and 2.5 ± 0.06) respectively, but the difference was not statistically significant ($p>0.05$; Table 3.1).

The curve for distribution of body condition scores of goats that were supplemented with minerals is approximately normal between the range of scores 2.0-3.0 (Fig. 3.4). There were more goats in the NS group with body scores below the recommended for breeding females than in the S group (Fig. 3.4).

Fig. 3.3: Body condition scores of 275 goats encountered in the survey.

Part (a). Percentage distribution of the body condition scores. The dashed line marks the body condition score recommended for breeding females. The solid line marks the optimum body score for breeding small East African goat (Skea, 1988).

Part (b). The numbers and fractions as a percentage of goats with condition scores in each range.

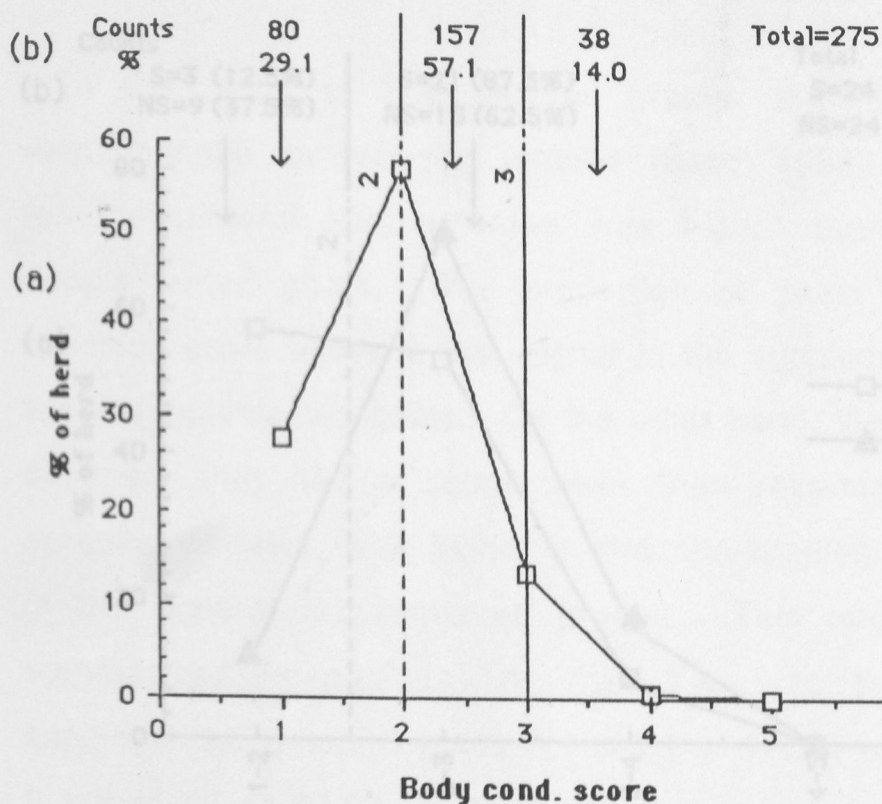


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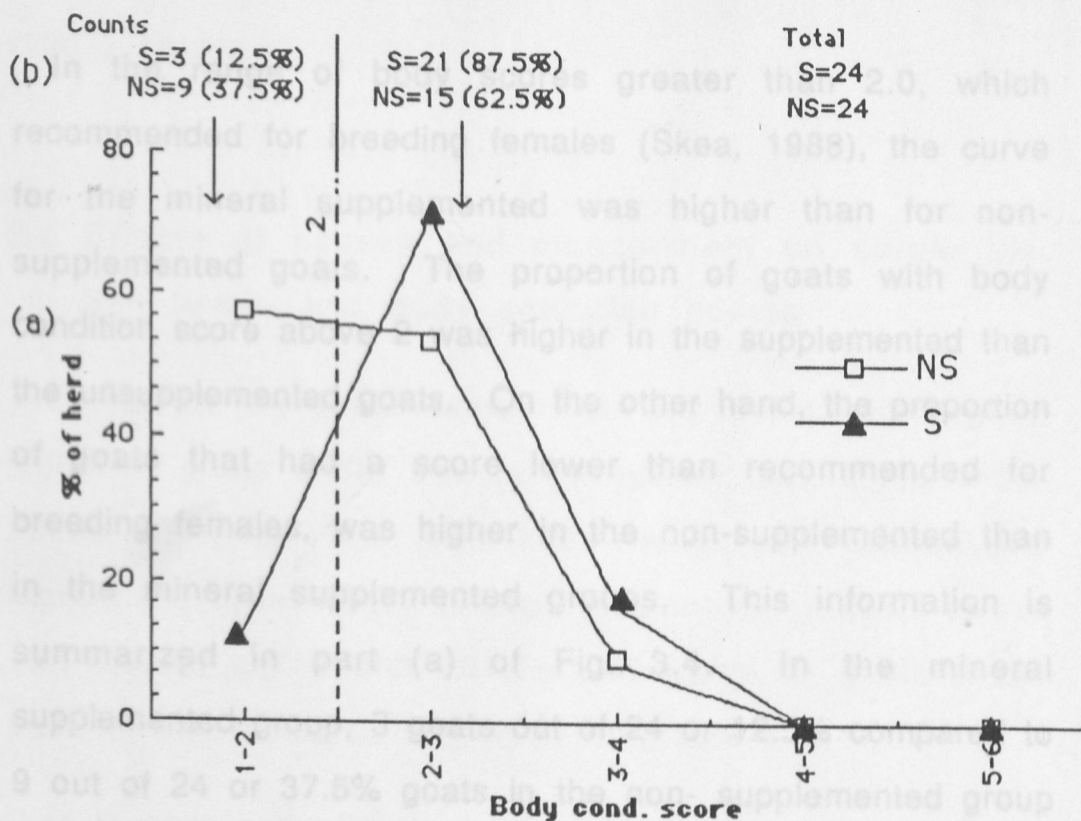


Fig. 3.4: Body condition scores in mineral supplemented (S) and unsupplemented goats (NS).

Part (a). Percentage distribution of body condition scores for the S and NS groups. The dashed line marks the lower limit recommended for breeding females (Skea, 1988).

Part (b). The numbers and fractions, as a percentage, of the goats with body condition scores within each range. The fraction is represented by the area under the curve in (a).

(1991) study

In the range of body scores greater than 2.0, which recommended for breeding females (Skea, 1988), the curve for the mineral supplemented was higher than for non-supplemented goats. The proportion of goats with body condition score above 2 was higher in the supplemented than the unsupplemented goats. On the other hand, the proportion of goats that had a score lower than recommended for breeding females, was higher in the non-supplemented than in the mineral supplemented groups. This information is summarized in part (a) of Fig. 3.4. In the mineral supplemented group, 3 goats out of 24 or 12.5% compared to 9 out of 24 or 37.5% goats in the non-supplemented group had body condition scores below that recommended for breeding females. The rest 21 out of 24 representing 87.5% of goats in the mineral supplemented group had body scores above the recommended lower limit for breeding females (Skea, 1988).

These results suggest that cobalt deficiency was the cause of poor body conditions found in goats in this study. Similar findings have been reported in goats under laboratory conditions (Mgongo, et al., 1984; Mburu, 1991). Mburu (1991) obtained body condition scores ranging from 2.5 ± 0.18 to 2.7 ± 0.21 and a mean of 2.6 ± 0.11 in Co adequate goats which is similar to the body scores obtained in the Vit. B₁₂ adequate goats in the pastoral system. The mean body condition score, 2.5 ± 0.12 obtained in goats which were not offered mineral supplements compares favorably with a mean of 2.2 ± 0.99 obtained in Co deficient goats in Mburu's

(1991) study.

3.6 Effects of season and management on serum Vit. B₁₂ levels and body condition scores

During the dry season, serum Vit. B₁₂ levels were slightly higher in goats under free range system than those under mixed farming but difference was not statistically significant ($p>0.05$). The respective means were 162.1 ± 12.51 pg/ml and 161.6 ± 15.86 pg/ml in goats under pastoral and mixed farming systems (Table 3.4).

In the wet season, serum Vit. B₁₂ in goats under pastoral system (283.6 ± 20.21 pg/ml) was significantly higher ($p<0.001$) than 177.0 ± 12.91 pg/ml in goats under mixed farming system (Table 3.4).

Body Score	1	2.8 ± 0.06	2.8 ± 0.07
	2	2.8 ± 0.10	2.4 ± 0.06
Bld. Glv. x10 mg/100 ml	1	4.1 ± 0.09	4.0 ± 0.36
	2	4.0 ± 0.1	3.8 ± 0.19

Key:

* -Statistically significant at 95%

** -Statistically significant at 99%

mgt 1 -pastoral system.

mgt 2 -mixed farming systems.

Table 3.4: Serum Vit. B₁₂, concentrations, body scores and blood parameters in goats under pastoral and mixed farming systems in the wet and dry seasons.

Parameter	mgt	dry	wet
Vit. B ₁₂ pg/ml	1	162.1±12.51	283.6±20.21 **
	2	161.6±15.86	177.0±12.91*
Hb gm/100 ml	1	9.3±0.21 **	8.7±0.21
	2	8.3±0.26	8.7±0.34
PCV. %	1	24.6±0.46 *	22.7±0.38
	2	22.8±0.7	26.9±0.84
RBC x10 ⁶ /mm ³	1	13.3±0.3	11.8±0.38
	2	12.8±0.42	12.6±0.50
MCV cu.μ	1	20.1±0.23	20.8±0.29
	2	20.9±0.41	20.6±0.39
WBC x10 ³ /mm ³	1	12.7±0.51	11.1±0.38
	2	13.7±0.47	10.5±0.44
Body Score.	1	2.8±0.06	2.6±0.07
	2	2.6±0.10	2.4±0.06
Bld. Glu. x10 mg/100 ml	1	4.1±0.09	4.0±0.38
	2	4.0±0.1	3.6±0.19

Key:

* -Statistically significant at 95%

** -Statistically significant at 99%.

mgt 1 -pastoral system.

mgt 2 -mixed farming systems.

The highest vitamin B₁₂ levels were obtained in the wet season in goats in the pastoral system and the lowest levels were found in the dry season in goats under mixed farming. These results suggest that wet season coupled with good management helped to decrease the incidence of occurrence of cobalt deficiency in goats. The poor management factors combined with low pasture cobalt availability in the dry season explains the very low serum Vit. B₁₂ levels in goats of mixed farmers in the dry season.

The significantly higher mean serum Vit. B₁₂ levels in goats reared under pastoralism compared to goats under mixed farming and also in the mineral supplemented than non-supplemented is consistent with higher body condition scores in these goats respectively. There was a tendency for higher RBC counts, Hb concentrations, blood glucose concentrations in goats reared under the pastoral farming system than those found in the mixed farms. This suggests that the anaemia and poor body condition observed in the goats were as a result of Vit. B₁₂ deficiency. This is in support of previous findings (Mgongo, et al., 1984). Mgongo, et al. (1984) obtained a very striking difference in body condition between Co treated and non-treated goats.

Effects of season and management on body condition scores

Body condition scores were higher in goats reared under pastoral than in the mixed farming systems in the dry season (means±S.E.M., 2.8±0.06 and 2.6±0.10 respectively; Table 3.4), but the difference did not attain statistical

significance. Goats in the pastoral system had consistently higher scores than those in the mixed farms in both seasons with the highest mean body score in the dry season.

These results suggest that better management in goats reared under the pastoral farming system coupled with higher dry matter intake (DMI) in the dry season resulted in better body conditions in goats. Innadequate crude protein intake together with reduced DMI in the rush pastures (Underwood, 1981) prevented the benefits of higher dietary cobalt intake to be reflected significantly in improved body condition of the goats reared under pastoralist system in the wet season.

The effects of poor management and reduced DMI are reflected in the very poor body conditions observed in goats reared under mixed farming in the wet season. The benefits of good management are reflected in higher body conditions in goats reared under pastoralist system in both the dry and wet season suggesting that the management was more important than season in determining the nutritional status of the goats.

3.7 Blood picture in cobalt deficient goats

Erythrocyte counts ranged between a minimum of $6.05 \times 10^6/\text{mm}^3$ and $21.65 \times 10^6/\text{mm}^3$. The mean was $12.6 \pm 0.2 \times 10^6/\text{mm}^3$ which is below the normal average of $13.0 \times 10^6/\text{mm}^3$ (Schalm, 1965) expected for goats (Table

3.5).

Out of 221 goats sampled, 8 (3.62%) had red blood cell (RBC) counts below the normal range ($8.0-18.0 \times 10^6/\text{mm}^3$) and were thus anaemic. A greater proportion, 118 (53.4%) out of 221 goats that had RBC counts within the normal range had values below the mean expected for goats and therefore were at the risk of becoming anaemic (Fig. 3.8).

Hb concentrations ranged from 4.2 -12.9 g/100 ml. The mean Hb concentration, 8.8 ± 0.12 g/100 ml, was below the normal average of 11.0 g/100 ml for goats (Table 3.5). Seventy-one out of 215 (23.0%) of the goats sampled had Hb values below the normal range, (8.0-14.0 g/100 ml) for goats and were anaemic while 125 out of 215 (58.1%) had Hb concentrations below the average of 11 gm/100 ml for goats and therefore were at risk of becoming anaemic (Fig. 3.6).

From the PCV levels, out of 235 goats, 27 or 11.3% had PCV% values below the lower limit for goats, the normal range being 19.5-38.5 % (Fig. 3.7 and Table 3.5). Among 208 goats that had PCV% levels within the normal range, 182 constituting 75.8% of the total 235 had levels below the average 28.5% expected for goats and were therefore at risk of becoming anaemic.

Out of 221 goats analysed, 95 (43.0%) had RBC counts within the normal range and higher than the mean ($13.0 \times 10^6/\text{mm}^3$) expected for goats. Hb concentrations revealed 19 out of 215 (8.8%) goats that had levels above

the average expected for goats (Fig. 3.4) and safe from developing anaemia. Only 26 or 11.3% out of 235 goats sampled had adequate PCV% levels (Fig. 3.7).

The MCV values were within the normal range (15.0-30.0 cu. μ) expected for goats. Out of 221 goats, 189 (or 86%) had MCV values less than the mean (22.8 cu. μ) while 30 (14%) had MCV values above 22.8 cu. μ , the average for goats (Schalm, 1965). The mean MCV, 20.6 cu. μ was slightly below the average required for goats (Table 3.5 and Fig. 3.5).

PCV %	24 $\pm$ 0.29	9.0-38.0	19.5-38.5 Avg. 28.5
MCV cu. μ	20.6 $\pm$ 0.16	15.0-32.5	15.0-30.0 Avg. 22.8
WBC $\times 10^3$ /mm ³	12.1 $\pm$ 0.24	1.4-22.5	4.0-16.0 Avg. 9.0
Blood glucose $\times 10$ mg/100 ml	4.0 $\pm$ 0.07	1.7-9.1	4.0-6.0
Body score	2.6 $\pm$ 0.038	1-4.5	$\leq$ 2.0

Key:
Avg = Average
obs. = observed

Table 3.5: Means and observed ranges of serum Vit. B₁₂ levels, body condition scores and blood parameters in comparison to the normal ranges for goats.

parameter	mean±SEM	obs. range	normal range
Vit. B ₁₂ pg/ml	205.5±9.37	20.2-937.5	>370
Hb g/100 ml	8.8±0.12	4.2-12.9	8.0-14.0 Avg. 11.0
Rbc count x10 ⁶ /mm ³	12.6±0.20	6.0-21.7	8.0-18.0 Avg. 13.0
PCV %	24±0.29	9.0-38.0	19.5-38.5 Avg. 28.5
MCV cu. μ	20.6±0.16	15.0-32.5	15.0-30.0 Avg. 22.8
WBCx10 ³ /mm ³	12.1±0.24	1.4.0-22.5	4.0-16.0 Avg. 9.0
Blood glucose x10 mg/100 ml	4.0±0.07	1.7-9.1	4.0-6.0
Body score	2.6±0.038	1-4.5	>2.0

Key:

Avg = Average

obs. = observed

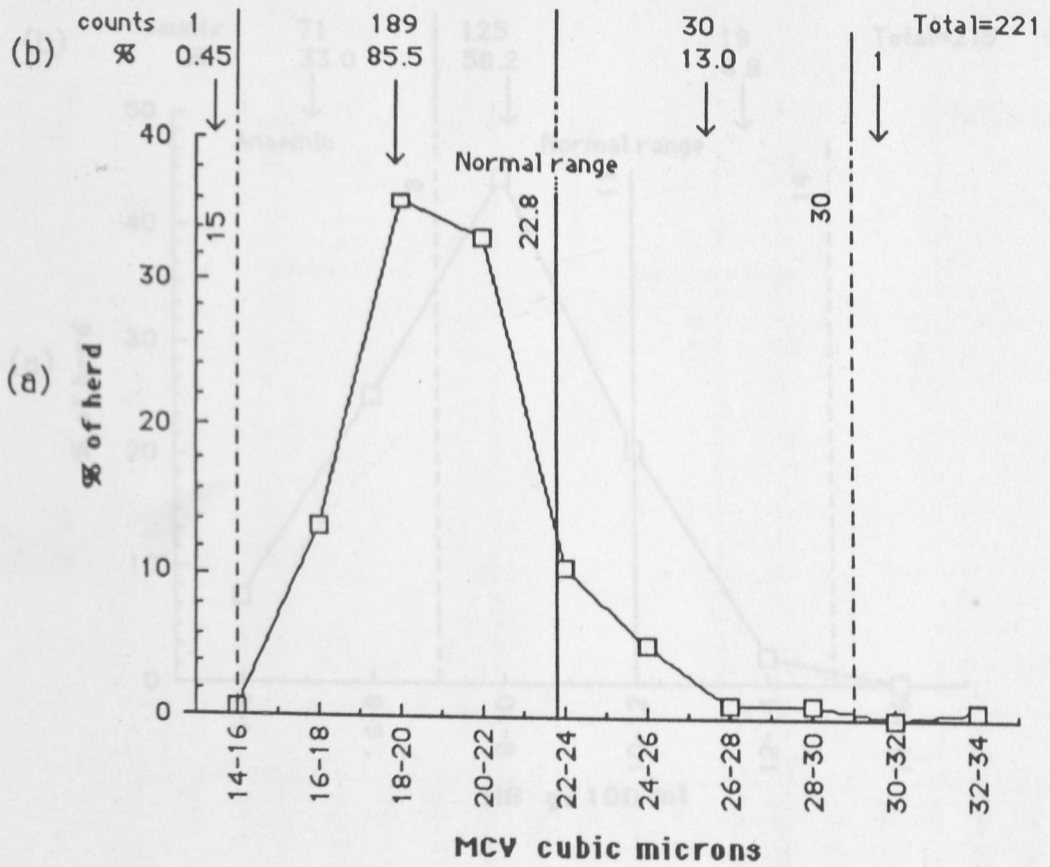


Fig. 3.5: Part (a). Percentage distribution of haemoglobin concentrations (Hb g/100 ml) of the goats. The dashed lines

Fig. 3.5: Part (a). Percentage distribution of mean corpuscular volume (MCV) for 221 goats encountered in the survey. The dashed lines mark the limits of the normal range while the solid line marks the average value in goats.

Part (b). The numbers and percentages of goats with MCV values within each range.

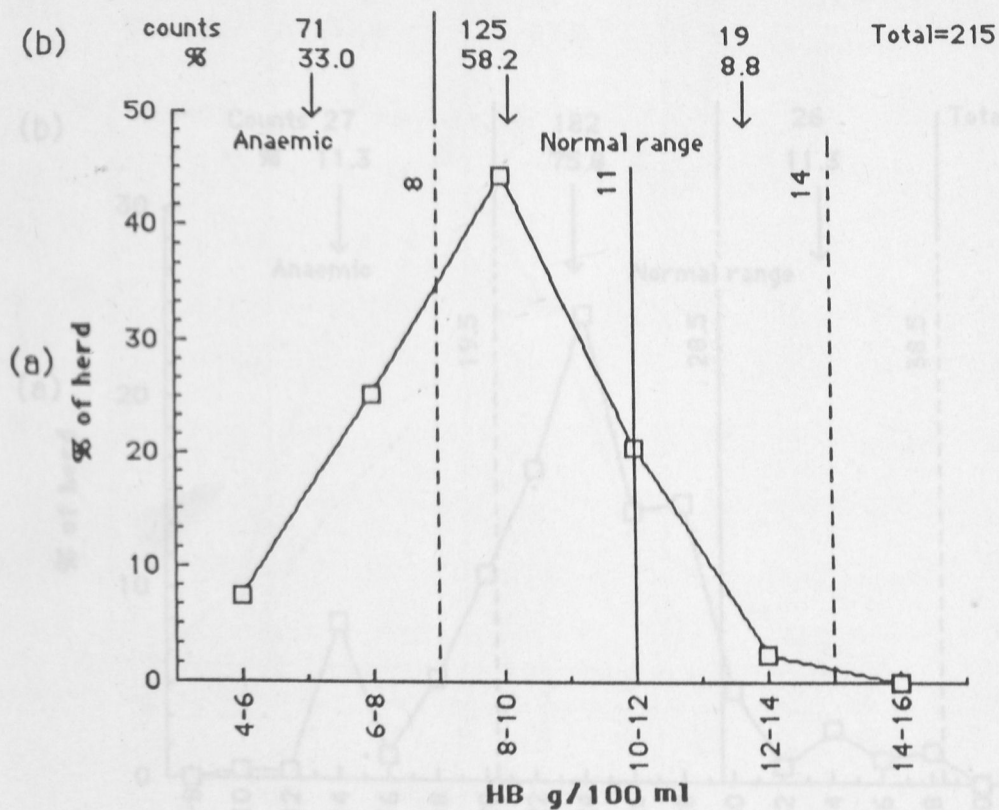


Fig. 3.6: Part (a). Percentage distribution of haemoglobin concentrations (Hb g/100 ml) of the goats. The dashed lines mark the anaemic and normal ranges and the complete line marks the average for goats. The area under the curve within the range limits represents the fraction of goats in each range.

Part (a). Percentage distribution of Packed cell volume
Part (b). The numbers and percentages of goats with Hb concentrations in the anaemic, and normal ranges for goats.

range of PCV%. The dashed lines define the anaemic and normal ranges for goats. The solid line marks the average.

Part (b). The numbers and percentages of goats with PCV levels in the corresponding ranges.

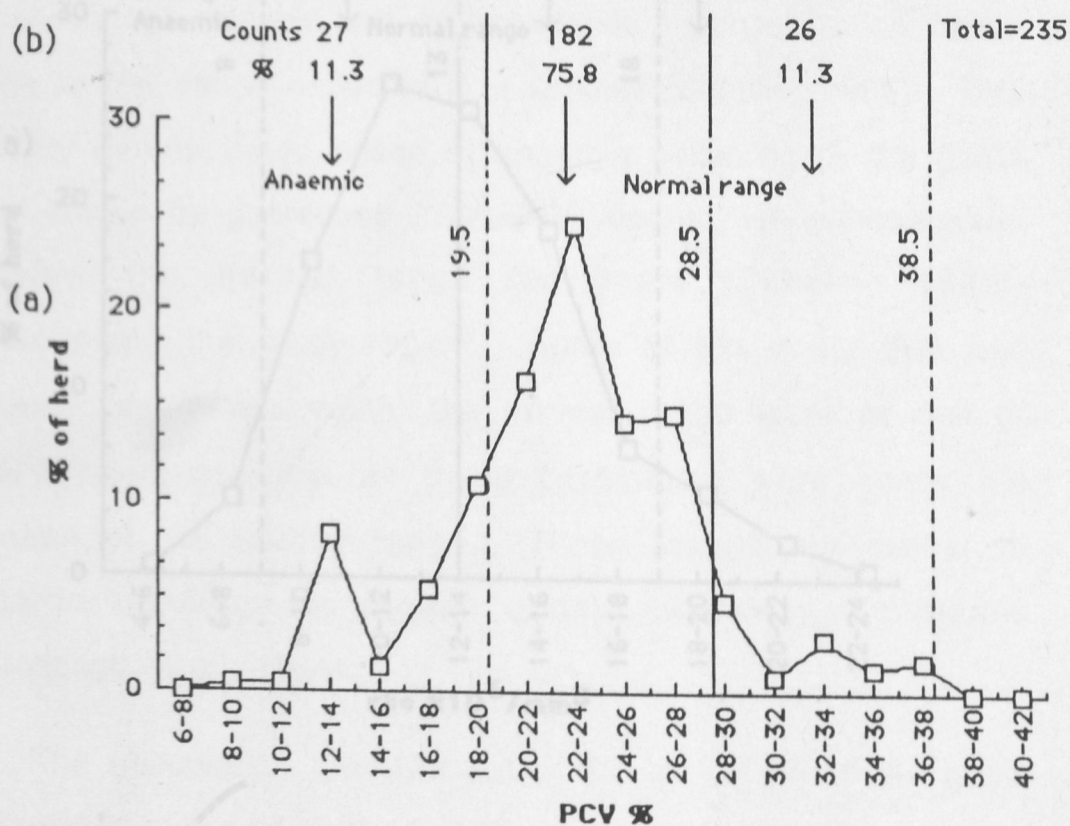


Fig. 3.6: Red blood cells counts (rbc $\times 10^6/\text{mm}^3$) of the goats

Fig. 3.7: Packed cell volume (PCV%) of the goats of the survey.

Part (a). Percentage distribution of Packed cell volume (PCV%) among the goats. Each point represents the percentage of the sampled goats with the corresponding range of PCV%. The dashed lines define the anaemic and normal ranges for goats. The solid line marks the average.

Part (b). The numbers and percentages of goats with PCV levels in the corresponding ranges.

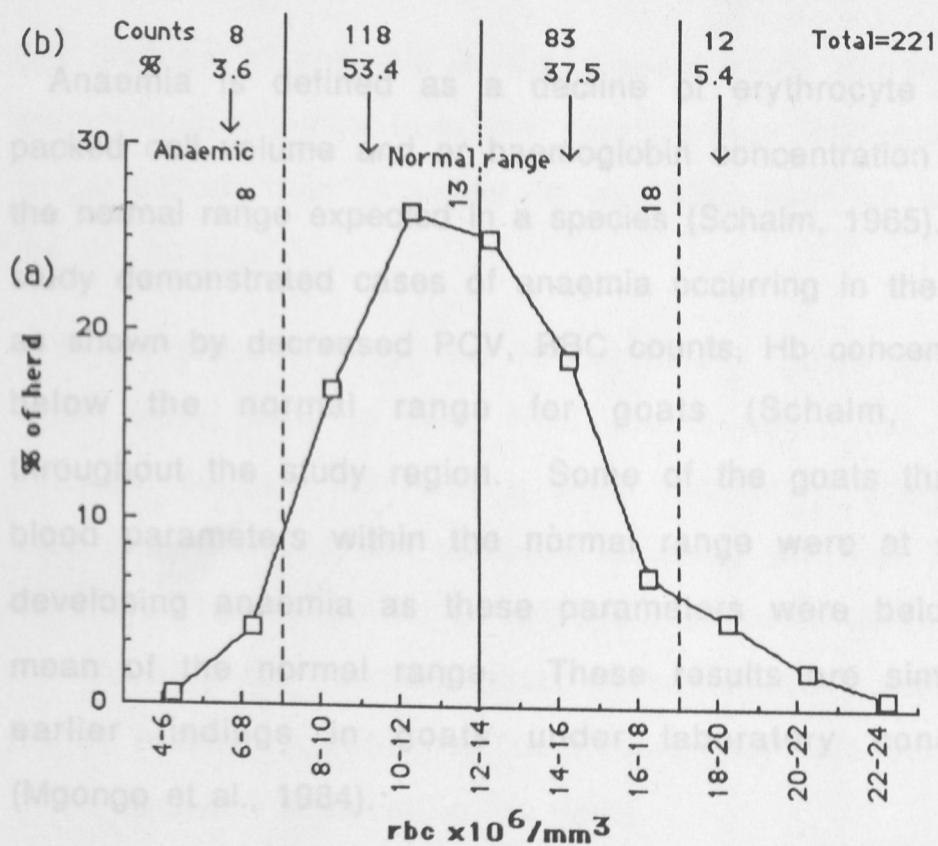


Fig. 3.8: Red blood cells counts ($\text{rbc} \times 10^6/\text{mm}^3$) of the goats encountered in the study.

Part (a). Percentage distribution of the red blood cell counts ($\text{rbc} \times 10^6/\text{mm}^3$) obtained among the goats sampled. The dashed lines mark the upper and lower limits of the normal range for goats and the solid line marks the average.

Part (b). The numbers and percentages of goats with RBC counts in the corresponding ranges.

Anaemia is defined as a decline of erythrocyte count, packed cell volume and or haemoglobin concentration below the normal range expected in a species (Schalm, 1965). This study demonstrated cases of anaemia occurring in the goats as shown by decreased PCV, RBC counts, Hb concentration below the normal range for goats (Schalm, 1965), throughout the study region. Some of the goats that had blood parameters within the normal range were at risk of developing anaemia as these parameters were below the mean of the normal range. These results are similar to earlier findings in goats under laboratory conditions (Mgongo et al., 1984).

The observation that 126 out of 221 or 57.0% of the goats samples analysed showed RBC counts less than the average, $13.0 \times 10^6/\text{mm}^3$ for goats demonstrates anaemia. The occurrence of anaemia is also demonstrated by 27 out of 235 or 11.3%, of the goats which had PCV levels below the lower limit of the normal range for goats. From the Hb concentrations, 71 (or 23 %) out of 215 goats had values below the normal range and thus were anaemic. This demonstrated a clear manifestation of anaemia in some of the goats encountered in the survey.

The Hb concentrations as well as the RBC counts in goats in the present survey were comparable to values obtained in Co deficient goats fed on hay from Nakuru (Mburu, 1991). However, overt anaemia does not manifest in goats on a cobalt deficient diet for 23 weeks (Mburu, 1991) therefore,

the findings of anaemia in the present study suggest that dietary cobalt intake from the herbage was inadequate for longer periods than 23 weeks i.e. extending over the wet and the dry season.

In the present study, the 12 out of 221 goats (or 5.4%) which were found to have RBC counts above the normal average, suggest that only a small fraction of goats were safe from anaemia and compare favorably with the findings of Mburu (1991) reported an average RBC count of $14.9 \pm 1.13 \times 10^6/\text{mm}^3$ in Co adequate goats under laboratory conditions. These results suggest that cobalt deficiency was the cause of the anaemia observed in the goats.

A small fraction of the goats studied i.e. 19 out of 215 or 8.8%, were not anaemic as reflected in the levels of Hb concentrations and 26 out of 235 (11.3%) goats showed PCV levels above the normal average for goats and were safe from anaemia. Most of the goats (201 out of 221 or 90.9%) had RBC counts within the normal range. The present study suggests that under field conditions, some cobalt deficient goats develop anaemia while in others, anaemia may not occur in Co deficiency. In marginal cobalt deficiency anaemia is not a consistent finding (Underwood, 1981; Mgongo et al., 1984); and this was probably the case where the haemogram in goats encountered in the survey was not supportive of anaemia.

It is significant to note that only a few goats manifested overt anaemia while the greater proportion showed mild

anaemia with the haemogram tending towards normal but skewed towards anaemia. These results support earlier findings in goats under laboratory conditions where it was demonstrated that cobalt deficient goats showed mild anaemia with the haemogram within the normal range but with a bias towards the lower values of the range (Mburu, 1991). The possibility of anaemia arising from other causes e.g. helminthiasis was not ruled out in the present study.

Effects of different farming systems, season and management on the haemogram

The haemogram in the different seasons and management revealed that Hb concentration and PCV levels were significantly higher ($p < 0.05$) in goats under pastoral system than in goats under mixed farming in the dry season but were not significantly different in the wet season (Table 3.5). The other blood parameters did not show significant differences between the two types of management regardless of the season.

From the combined dry and wet seasons result, RBC counts and Hb concentrations were higher in goats reared under the pastoral than the mixed farming systems. MCV values for goats in the pastoral were slightly lower than in the mixed farming system (20.5 ± 0.19 and 20.81 ± 0.29 ; means $\pm$ S.E.M.) respectively (Table 3.5).

Varying numbers of goats in the S and NS groups fell in the normal and anaemic ranges for Hb concentrations, PCV% and RBC counts and mineral supplementation did not seem to

have resulted in a significant improvement on the haemogram. The MCV levels were within the normal range in both mineral supplemented and non-supplemented goats.

Underwood, (1977) reported that the first discernible response to Co supplementation or Vit. B₁₂ injection in ruminants is a rapid improvement in appetite and body weight, and blood picture improvement was delayed. Mgongo et al. (1984) reported consistently low blood Hb concentration, PCV% and RBC counts after the 9th week after initiation of cobalt deficiency when the serum Vit. B₁₂ levels were below 250 pg/ml.

In the present study, the mineral supplemented goats demonstrated a case of marginal Vit. B₁₂ deficiency status. This suggests that in sub-clinical deficiency, the blood picture is not diagnostic of Co deficiency especially in the varied field environment and is perhaps useful in cases of overt deficiency. However, there's a tendency towards a normocytic anaemia in marginal cobalt deficiency in agreement with earlier findings in cobalt deficient goats under laboratory conditions (Mgongo et al., 1984).

In a study to elucidate the mechanism by which Vit. B₁₂ deficiency causes anaemia (Gombe and Verjee, 1976), it was found that the levels of erythrocyte glutathione peroxidase increased during cobalt deficiency while the levels of glutathione reductase enzyme (GSH) increased. When the goats are given cobalt supplement, PCV starts rising while GSH takes sometime and then starts decreasing. Human

beings with Vit. B₁₂ deficiency anemia have increased levels of GSH similar to Vit. B₁₂ related anaemia in ruminants. Increased GSH levels in Vit. B₁₂ deficiency is thought to be compensatory to prevent further loss of haemoglobin through oxidative destruction.

The exact mechanism by which Vit. B₁₂ affects the haemopoietic system is not known (Chanarin, 1977). It is thought to be related to the effects of folate which is concerned with purines and pyrimidine synthesis. In Co deficiency, there's reduction of DNA synthesis. The red cells formed have abnormal DNA content. These cells die in the bone marrow and are reabsorbed. Some of the cells may mature into macrocytic erythrocytes but how this is brought about is not clearly understood.

In the present study, a case of normocytic anaemia in cobalt deficient goats is demonstrated by the MCV levels which are largely within the normal range. In humans, mild cases of normocytic anaemia have been found in marginal cases of Vit. B₁₂ deficiency (Carmel et al., 1989). Microcytic anaemia has been reported in Vit B₁₂ deficient calves (Filmer, 1933 cited by Quirk and Norton, 1984). There is dispute as to the classification of anaemia in various species and other dietary factors e.g. copper and iron levels could influence the manifestation of anaemia (Underwood, 1981). Other factors are unknown (Carmel et al., 1989).

White blood cell counts in Vit. B₁₂ deficiency

The curve for white blood cell counts of the goats studied is nearly normal about the normal range for goats 4.0-14.0 $\times 10^3/\text{mm}^3$ (Schalm, 1965) (Fig. 3.9). Out of 227 goats, 171 (or 75.4%), had WBC counts within the normal range. Fifty-five or 24.2% of the sampled goats had WBC counts above the normal range for goats.

White blood cell (WBC) counts were lower in goats under pastoral farming system than those in the mixed farming system ($11.9 \pm 0.32 \times 10^3/\text{mm}^3$ and $12.4 \pm 0.37 \times 10^3/\text{mm}^3$; means $\pm$ S.E.M.) respectively but the difference was not statistically significant ($p > 0.05$; Table 3.3). The mean WBC counts were significantly ($P < 0.001$) higher in dry ($13.2 \pm 0.35 \times 10^3/\text{mm}^3$) than wet ($10.9 \pm 0.029 \times 10^3/\text{mm}^3$) season respectively. This results suggest that higher WBC counts were associated with Vit. B₁₂ deficiency.

Part (b). The numbers and fractions as a percentage of the goats with WBC counts in the corresponding ranges.

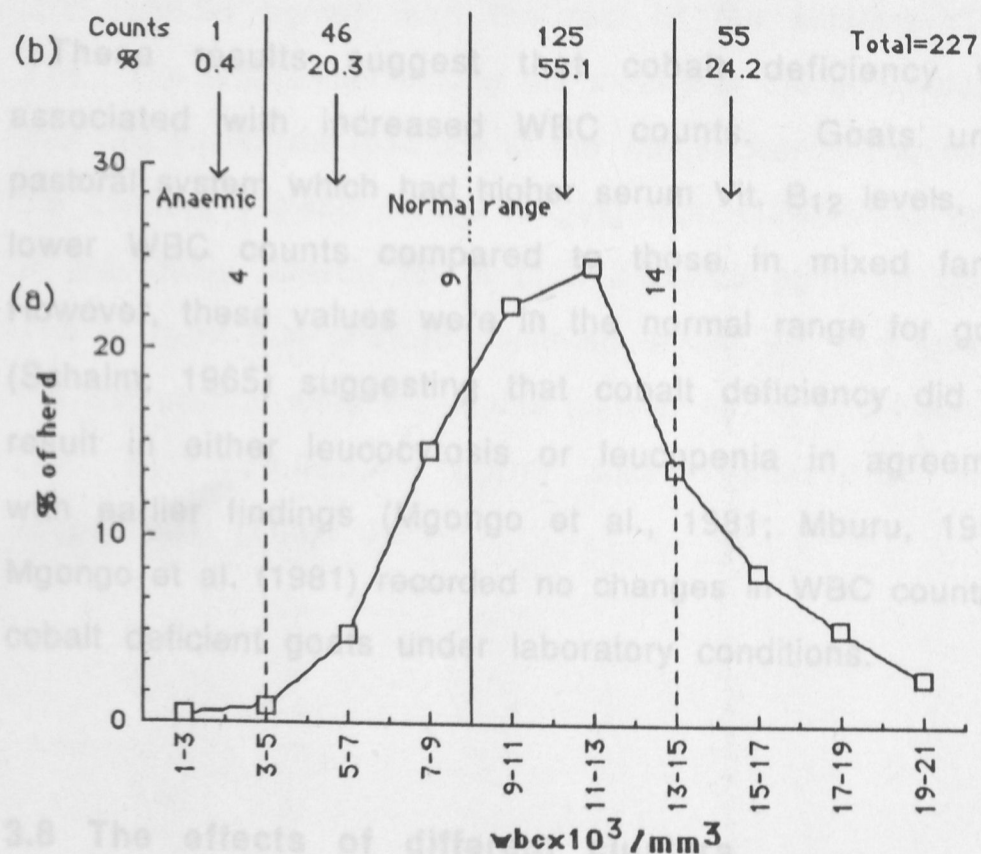


Fig. 3.9: Part (a). Percentage distribution of white blood cell ($\text{WBC} \times 10^3/\text{mm}^3$) counts for the goats encountered in the survey. The dashed lines mark the normal range and the solid line marks the average for goats.

Part (b). The numbers and fractions as a percentage of the goats with WBC counts in the corresponding ranges.

(405.3±36.54 pg/ml) than the rest of the clusters (Table 3.6). These results suggest that cobalt deficiency was associated with increased WBC counts. Goats under pastoral system which had higher serum Vit. B₁₂ levels, had lower WBC counts compared to those in mixed farms. However, these values were in the normal range for goats (Schalm, 1965) suggesting that cobalt deficiency did not result in either leucocytosis or leucopenia in agreement with earlier findings (Mgongo et al., 1981; Mburu, 1991). Mgongo et al. (1981) recorded no changes in WBC counts in cobalt deficient goats under laboratory conditions.

3.8 The effects of different clusters

Most of the clusters had comparable serum Vit. B₁₂ levels without much difference from one cluster to the other (Table 3.6). One cluster in Gilgil (Cluster no. 7; Ngema) showed significantly higher ($p<0.05$) serum Vit. B₁₂ concentrations than the other clusters in dry season (277.1 ± 32.60 pg/ml dry season in Ngema compared to means ranging from 124.9 ± 14.50 to 199.6 ± 23.70 pg/ml in the other clusters). There was no significant differences ($p>0.05$) among mean serum Vit. B₁₂ levels in all the other clusters. The cluster that showed minimum serum Vit B₁₂ levels in dry season were Kariandusi around Lake Elementaita with mean serum Vit. B₁₂, $90.9\pm23.17.61$ pg/ml.

During the wet season the cluster in Ngema location had significantly higher ($p<0.05$) serum Vit. B₁₂ levels

Table 3.6. Serum Vit. B₁₂ concentrations, body condition scores, blood parameters, reproductive rates and weaning rates for the goats from different clusters.

Table 3.6. Serum Vit. B ₁₂ concentrations, body condition scores, blood parameters, reproductive rates and weaning rates for the goats from different clusters.											
Parameter		1	2	3	4	5	6	7	8	9	10
Vit. B ₁₂ (pg/ml)											
PGC count (x10 ⁹ /ml)											
Hb (g/100 ml)											
Red blood cells (x10 ¹² /ml)											
Body condition score											
Reproductive rate											
Weaning rate no. of kids/does/yr											
Key:											
1-Suswa farms											
2-Moroti farms											
3-Mai-Mahiu farms											
4-Mai-Mahiu (2) farms											
5-Kiambogo farms											
6-Kinungu farms											
7-Nguswa farms											
8-Kariakoba farms											
9-Jomo Nyuma farm											
10-Defuncted/abandoned system in small ruminant project (CRSP) farm											

(405.3±36.54 pg/ml) than the rest of the clusters (Table 3.6). The differences among the means of the other clusters was not significant (p>0.05) in the wet season. The rest of the clusters showed means ranging from (126.0±6.40 pg/ml) in Mai-Mahiu, cluster no. 4 to 272.2±7.03 pg/ml in Suswa. The clusters that showed minimum serum Vit. B₁₂ levels in the wet season were Mai-Mahiu (cluster no. 4) and Kiambogo (no. 5): 126.0±6.40 pg/ml and 142.0±16.82 pg/ml respectively (Table 3.6).

Table 3.6. Serum Vit. B₁₂ concentrations, body condition scores, blood parameters, reproductive rates and weaning rates for the goats from different clusters.

Parameters		Clusters									
		1	2	3	4	5	6	7	8	9	10
Vit. B ₁₂ pg/ml	S1	145 ±14.5	168 ±20.75	184.2 ±47.49	151.8 ±25.52	124.9 ±14.5	134.0 ±39.06	277.1** ±32.60	90.9 ±17.61	199.6 ±23.70	184.0 ±20.07
	S2	272.2 ±7.03	236.9 ±0.53	ND	126.0 ±6.40	142.0 16.82±	173.8 ±18.4	405.3** ±36.54	162.6 ±7.05	201.1 ±11.15	ND
RBC count x10 ⁶ /mm ³	S1	13.9 ±0.06	11.8 ±0.68	12.6 ±0.58	12.5 ±0.58	ND	14.3 ±0.82	12.5 ±0.54	13.2 ±0.69	13.6 ±0.55	ND
	S2	14.6 ±0.75	ND	ND	12.8 ±0.89	15.3 ±1.06	13.4 ±0.83	10.3 ±0.41	11.0 ±0.78	10.4 ±0.27	ND
Hb gm/100 ml	S1	9.5 ±0.43	7.4 ±0.5	8.2 ±0.52	8.1 ±0.42	ND	9.3 ±0.49	8.6 ±0.34	8.9 ±0.59	10.3 ±0.18	ND
	S2	9.9 ±0.27	ND	ND	ND	9.0 ±0.83	9.4 ±0.41	8.0 ±0.49	7.6 ±0.30	ND	ND
Bld glucose x10 mg/100 ml	S1	3.8 ±0.12	4.0 ±0.15	4.0 ±0.31	4.3 ±0.23	4.1 ±0.12	3.6 ±0.20	4.4 ±0.27	4.2 ±0.24	3.8 ±0.12	4.2 ±0.17
	S2	4.0 ±0.38	4.0 ±0.26	ND	ND	ND	ND	ND	ND	ND	ND
Body co. score	S1	3.3 ±0.14	2.8 ±0.22	2.2 ±0.19	2.8 ±0.25	2.6 ±0.18	2.7 ±0.19	2.7 ±0.12	2.6 ±0.09	2.7 ±0.11	2.2 ±0.12
	S2	2.2 ±0.17	2.3 ±0.08	ND	2.8 ±0.11	2.2 ±0.15	2.5 ±0.12	2.4 ±0.10	2.6 ±0.12	2.3 ±0.09	ND
PCV %	S1	26.5 ±1.49	21.5 ±1.42	22.6 ±1.53	24.7 ±1.38	23.8 ±1.0	24.7 ±1.38	25.3 ±1.21	24.6 ±0.72	22.9 ±0.43	ND
	S2	23.5 ±0.54	ND	ND	27.2 ±0.77	24.1 ±1.75	25.3 ±0.92	21.8 ±0.59	20.9 ±0.73	28.6 ±1.51	ND
MCV cu.µ	S1	20.4 ±0.25	21.0 ±0.71	20.9 ±0.74	20.5 ±0.39	ND	21.1 ±1.07	19.8 ±0.44	20.8 ±0.43	19.5 ±0.60	ND
	S2	18.4 ±0.27	ND	ND	21.0 ±0.37	20.7 ±0.40	20.0 ±0.66	22.0 ±0.41	21.9 ±0.59	20.5 ±0.82	ND
WBCx10 ³ /mm ³	S1	12.0 ±0.46	12.7 ±1.00	13.6 ±1.12	14.7 ±0.84	ND	14.1 ±0.71	12.0 ±1.33	15.4 ±1.13	11.7 ±0.81	ND
	S2	13.3 ±0.94	ND	ND	10.6 ±0.57	10.1 ±1.06	11.6 ±0.57	11.2 ±0.66	8.4 ±0.54	10.9 ±0.70	ND
Repro. rate kids/doe/yr		0.6	1.0	1.0	0.8	1.1	0.8	0.8	1.0	1.4	ND
Weaning rate no. of weaners/doe/yr		0.6	0.9	0.4	0.8	0.9	0.7	0.8	0.6	0.8	ND

Key:

* -Statistically significant at 95%

** -Statistically significant at 99%

ND -not determined

S1 -dry season

S2 -Wet season

1-Suswa farms

2-Mirela farms

3-Mai-Mahiu farms

4-Mai-Mahiu (2) farms

5-Kiambogo farms

6-Kinungi farms

7-Ngema farms

8-Kariandusi farms

9-John Nimmo farm

10-Corraborative research in small ruminant project (CRSP) farm

Soil analysts have reported no significant differences in the soil types in this region (Siderius and Muchena, 1977). This implies that perhaps no differences in cobalt concentrations are expected over the study region as this is affected by the type of soil in an area (Mills, 1981). This is supported by the results obtained in this study. The serum Vit. B₁₂ levels showed variations among the clusters but the ranges in most clusters overlap. This suggests that there were no significant differences in the soil and pasture cobalt available to the goats over the region studied.

The goats in the clusters in Gilgil, Ngema location had higher serum Vit. B₁₂ concentrations than all the other clusters but this was shown to be due to better management factors. This is made clear by the comparison between goats in the different farming systems; free grazing and mixed farming, and also the mineral supplemented and non-supplemented goats.

The body condition scores and blood parameters varied within considerably narrow ranges from one farm and cluster to the other. This suggests that the goats fed on pastures with similar growth efficiency and the problem is widespread in the area. Previous studies have shown that where mineral deficiencies occur, the problem is normally over a wide range of area (Underwood, 1981; Mills, 1981; Van Eys, 1985).

The variation of serum Vit. B₁₂ levels from one goat to another within the same cluster, was only mild. The

haemogram was similar in most farms and among the clusters. This is clear from the low standard errors of the means.

In a few farms, goats were found to be unthrifty with body conditions less than 2.0 and very low serum Vit. B₁₂ levels. Such goats manifested anaemia in the blood picture and there was a history of deaths of kids and adults from various causes. The severe cobalt deficiency in goats in these farms was associated with poor managements and lack of mineral supplementation.

From the questionnaire and observations made during the farms visits, it was found that goats grazed in private farms and in common land. Goats from the same locality grazed on the same pastures and little difference could be found in serum Vit. B₁₂ concentrations in goats from one farm to the other in the same locality. Rarely did the goats get commercial feed supplements and differences arising from cobalt in such feeds were not expected. However, it was difficult to analyse data from goats belonging to individual farmers because of the variation of the numbers of goats studied in each farm.

3.9 Effects of cobalt deficiency on Blood glucose levels

Blood glucose levels in goats in the present study were near the normal range (40-60 mg/100 ml of blood) expected for goats (Breazile, 1971) irrespective of the goats' levels of serum Vit. B₁₂. Most of the goats had blood glucose levels near the lower limit of 40 mg/100 ml while a few goats were found to have blood glucose levels below the normal limits.

Blood glucose levels were higher in dry than wet season (means $\pm$ S.E.M, 40.3 ± 0.6 and 38.0 ± 2.0 mg/100 ml) but the difference did not attain statistical significance ($p > 0.05$). In both seasons, the values were near the normal range of 40-60 mg/100 ml (Breazile, 1971) expected for goats.

These results suggest that low blood glucose levels is a late manifestation of Vit. B₁₂ deficiency in goats similar to reports in cattle (Musewe and Gombe, 1980). Cases of cobalt deficiency showing low serum Vit. B₁₂ levels (220 pmol/l) and decreased methylmalonyl CoA mutase activity, have been observed where serum glucose concentrations were the same in cobalt deficient and adequate sheep (Kennedy et al., unpublished).

Musewe and Gombe, (1980) found no significant differences in blood glucose concentrations in cattle which were Co adequate and deficient ones. These authors used Vit. B₁₂ to blood glucose ratios to reveal the animals which

Vit. B₁₂ to blood glucose ratios to reveal the animals which were marginally Vit. B₁₂ deficient and suggested that animals which were borderline deficient in Vit. B₁₂ could be revealed by the ratio. In the present study definite cases of Vit. B₁₂ deficiency were demonstrated by low values of serum B₁₂ concentrations below 200 pg/ml and supported by the occurrence of anaemia, poor body conditions and poor reproductive performance and the serum Vit. B₁₂ to glucose ratios were not studied.

Although plasma glucose is under tight hormonal control, it is surprising that an alteration in plasma glucose is a late manifestation in cobalt deficiency in goats given the importance of propionate in gluconeogenesis and the severe impairment of methylmalonyl CoA-mutase activity in cobalt deficiency (Peters and Elliot, 1984). A decrease in propionate supply from the rumen is expected as a result of decreased appetite and hence feed intake caused by Vit. B₁₂ deficiency (Marston et al., 1961).

Cobalt deficiency causes pituitary hyperplasia and hyperactivity resulting to an elevation of plasma levels of trophic hormones. The hypertrophy and hyperplasia of the adrenal and thyroid glands in cobalt deficiency (Mgongo et al., 1981) leads to an increase in plasma levels of adrenocorticotrophic hormone (ACTH) and thyroid stimulating hormone (TSH). ACTH and TSH affect the metabolism of glucose indirectly, ACTH through increased stimulation for release of glucocorticoids and TSH causes an increase in basal metabolic rate and therefore increased

glucose utilization. These hormones promote gluconeogenesis and decrease glucose utilization in the cells and thereby maintain blood glucose levels at normal ranges. Musewe and Gombe (1980) suggested that the effects of these hormones do not last long as their levels in plasma decline in later stages in Co deficient cattle. In chronic cobalt deficiency, the predominant effect might be that of impaired propionate metabolism leading to low blood glucose.

3.10 Reproductive performance in cobalt deficient goats

The results of reproductive rates and weaning rates are shown in Table 3.6. The low reproductive rates obtained throughout the region of study depict decreased fertility occurring as a result of Vit. B₁₂ deficiency. This is similar to previous findings in Co deficient goats under laboratory conditions (Mgongo et al., 1984) and cattle in field conditions (Musewe and Gombe, 1980). Mgongo et al. (1984), observed irregular and prolonged oestrous cycles which ceased after the 23rd week on Co deficient diet compared to regular cycles in supplemented goats. The irregular oestrous cycles corresponded with decreased plasma progesterone levels. Musewe and Gombe (1980) reported that cobalt deficiency in cattle under field conditions in some farms in this area where no mineral supplementation was done showed conception rates of 30% compared with

67% in mineral supplemented farms in the same vicinity.

Ovarian atrophy that occurs in prolonged cobalt deficiency (Mgongo et al., 1981) suggests that cobalt supplementation may not reverse the severe effects of fertility in prolonged cobalt deficiency. This explains the low reproductive rates observed in goats in many of the mineral supplemented farms in the present study.

The reproductive rates of goats under pastoralism was higher than for those reared under mixed farming systems e.g. 2 kids per doe per yr in some herds under free range system compared to less than 1 kid per doe per yr in most of the herds belonging to mixed farmers. Goats reared under free range system had better chances of avoiding Co deficiency and the problems of infertility associated with Vit. B₁₂ deficiency (Underwood, 1981; Mason and Mackay, 1983; Scheidner et al., 1991) than goats belonging to the mixed farms.

Many of the mixed farmers and some pastoralist farmers reported that kids which were born weak and underweight died a few days after birth. Some kids showed signs of pneumonia prior to death. Some of the weak kids were encountered during the study. Postnatal growth rate was low during the first 6-8 weeks after birth and many losses occurred during this period as derived from the questionnaire. Cobalt deficiency resulted to the birth of weak kids with reduced resistance to infection and kids were predisposed to diseases like pneumonia and helminth

Macpherson, 1986). High postnatal losses have been reported in cobalt deficient lambs (Duncan et al., 1981; Schneider, et al., 1991) and calves (Musewe and Gombe, 1980).

Poor breeding management in addition to Co deficiency contributed to the low reproductive performance in goats in the present study. Many farmers practiced little or no mating management in the flocks. A few entire males and some castrated males were found in each farm. This led to low reproductive rates since in a flock where no males are castrated, all males are available to mate the females. In most flocks, the ratio of one male to 20 or 25 females recommended for the small East African goat (Skea, 1988) was satisfied while in others there were one male to 30 or more females. Some herds did not have males and relied on matings during communal grazing which is inefficient. No breeding season was observed.

There was no control of age at first mating. Females mated young below 6-7 months for the small East African goat, with a low body weight either abort or they are unable to provide enough milk for the young (Skea, 1988). This leads to poor health in kids and the females' own body becomes stunted. This problem is prevalent especially among the peasant farmers and has been blamed for the general small size of the East African goat (Skea, 1988). The flocks were small e.g. less than 30 goats in a farm and rarely were new goats introduced. This resulted to inbreeding which when continued results in the appearance

inbreeding which when continued results in the appearance of undesirable characteristics e.g. decreased fertility, sterility, reduced body size and physical defects. These factors have partially contributed to the low reproductive performance observed in goats in this study.

Incidences of adult goats dying from unthriftiness were prevalent. In most of the mixed farms, there was a history of a few abortions occurring in goats. These depict weak does performing poorly in reproduction. The present study suggests that Vit. B₁₂ deficiency coupled with poor management contributed to the poor reproductive performance and overall low productivity in goats in the region covered by the study.

CONCLUSIONS

This study aimed at investigating the occurrence of Co related Vit. B₁₂ deficiency in goats kept under different management practices in small holder units in areas of the Rift Valley of Kenya, estimating the state of reproductive performance and body condition of the goats in these areas and relating these productivity indicators to the levels of plasma Vit. B₁₂. It also aimed to describe the farming management practices in the area of study and evaluate the extent that these practices predispose the goats to Vit. B₁₂ deficiency. The results have led to the following conclusions.

manifested by very low serum Vit. B₁₂ levels in goats over the whole region.

The deficiency is characteristically marginal with many goats tending towards the clinical form. The clinical form is demonstrated by the prevalent anaemia, very low reproductive performance, poor body conditions and in some cases severe unthriftiness leading to ultimate death. The deficiency also causes decreased immunity and the goats are predisposed to endemic diseases like contagious caprine pluropneumonia, other infections and helminth infestations. Decreased blood glucose is a late manifestation of cobalt deficiency in goats.

Cobalt deficiency in this region limits livestock production resulting to low reproductive performance and overall productivity in goats. The deficiency affects fertility leading to poor reproductive rates as well as survival of kids in the pre-weaning period leading to low weaning rates. The adults are predisposed to other diseases and their survival is reduced by cobalt deficiency.

The deficiency definitely occurs when goats are left to rely on pasture cobalt. Even when they are supplemented with cobalt incorporated mineral supplements, some goats still fall into clinical deficiency and most are marginally deficient.

Free grazing in combination with supplementation with cobalt rich mineral supplements, helps to reduce the incidence of occurrence of the deficiency but effective

cobalt rich mineral supplements, helps to reduce the incidence of occurrence of the deficiency but effective control would require strict management measures ensuring that all the goats receive enough of the cobalt salt, frequently and regularly so as to satisfy their body requirements.

Seasonal drought prevalent in this area enhances to some extent the occurrence of cobalt deficiency.

Suggestions for further work

The cobalt-incorporated anthelmintic found to have been used by the farmers in this study was Nilzan Plus® by Cooper Kenya Ltd TAL L 0216 which contains 0.382% cobalt according to the manufacturers. Most farmers who treated the goats for helminths did so every 3 months while some gave the anthelmintic irregularly at long intervals of say 6 months to an year. It is possible that the cobalt in the anthelmintic could help prevent the deficiency if it was available to individual goats in the required amounts and frequently (Kamau et al., personal communication). Further work to establish the dosage rates and frequency of administration of the cobalt incorporated anthelmintic preparation which would allow sufficient cobalt to be made available to all the goats in a herd and simultaneously achieve effective control of helminths, needs to be done.

The mineral supplements used contained 0.0014% cobalt

in Afya Bora® Superlick (Unga Ltd.), 0.02% cobalt in Macklic Supper® (Cooper Kenya Ltd.) and 9 mg/kg cobalt in Ready® block (Unga feeds Ltd.) and Baymix Lamba® mineral block (Bayer and Bayer). The solid block preparation compared to the granular form is convenient to transport and feed since it doesn't pour easily and it is economical in this respect. It is weather proof as the blocks are not easily washed away by the rain or melted by the sun as indicated by the manufacturers.

The mineral preparations that contained 0.0014% and 0.02% cobalt need to be re-evaluated to ascertain their effectiveness in preventing the occurrence of cobalt deficiency in goats and perhaps the other domestic species. The exact cobalt content in the formulations that would help to control cobalt deficiency effectively needs to be determined with reference to the soil and pasture cobalt contents in this region. The amounts of the mineral preparation required per animal needs to be verified for effective control of the deficiency.

Poor breeding management as well as cobalt deficiency produces to different extents the low reproductive performances and low productivity of goats in this region. Further work needs to be done under field conditions to establish the role of each of the poor breeding management and cobalt deficiency in the low productivity and poor reproductive performance of the goats.

Recommendations

Mineral supplementation at adequate levels in combination with free grazing is recommended in goats in the region covered by the study in order to prevent cobalt deficiency. The mineral preparation, Afya Bora® Ready Block which contains 9 mg Co/kg (Unga feeds Ltd.) and Baymix® Lamba mineral Block (Bayer and Bayer Ltd.) that contains a similar cobalt content can be used to prevent the deficiency in goats. The mineral preparations containing 0.0014% and 0.02% cobalt and the cobalt-incorporated anthelmintic might not provide adequate cobalt to the goats.

The farmers in this areas need to be properly educated about cobalt deficiency being a major limiting factor in their livestock production. They need to be enlightened on the importance of mineral supplementation especially the minerals that provide cobalt to the animals. This can be achieved through proper farm extension services to the farmers in the affected areas.

Proper breeding management advice needs to be given to the farmers to avoid the losses associated with this. The farmers need to be enlightened on the importance of maintaining the correct male to female ratio in the goats and detection of heat to improve the reproductive rates. Also the problem of inbreeding is quite pronounced and the farmers need to be advised on the importance of introducing new goats in the herds to avoid progressive deterioration of the herd productivity due to inbreeding.

This study emphasizes that adequate extension advice should be provided particularly to the small scale farmers in the cobalt deficient areas.

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APPENDIX

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Main water sources in wet season

- | | |
|---------------------|-------------------------------|
| 1. Roof catchment | 2. River, stream, pond, swamp |
| 3. Tap | 4. Dam |
| 5. Well or borehole | 6. Other |

Main water source in dry season

APPENDIX

GOAT HEALTH AND PRODUCTIVITY SURVEY NAIVASHA AREA

Date.....

Name of farmer.....

Location.....

Sub-location.....

Village/Area.....

Farm code.....

Part one

Language used in the interview

Person being interviewed.....

1. Head

2. Son

3. Herder

4. other, specify

Herd size: Total goats.....

Breeds of goats: local, cross, exotic

Reasons goats kept:

1. Cash

2. Prestige

3. milk

4. Tradition

5. Dowry

6. Manure

7. Investment

8. Other

Main water sources in wet season

1. Roof catchment

2. River, stream, pond, swamp

3. Tap

4. Dam

5. Well or borehole

6. Other

Main water source in dry season

1. Roof catchment
2. River, stream, pond, swamp
3. Tap
4. Dam
5. Borehole
6. Other

How far is main water source from the farm?

1. At the compound
2. Less than 1 hour
3. 1-1.5 hours
4. 1.5-2 hours
5. 2-3 hours
6. More than 3 hours

Do other animals use this source?

How are goats fed in the wet seasons?

1. Free range
2. Herded on farm
3. Herded on and off farm
4. Semi-zero grazed
6. Zero-grazed
7. Other

If Zero grazed, main feed source in wet season

1. Natural pasture
2. Fodder

3. Concentrates

4. Molasses

3. Other

If zero-grazed, main feed source in dry season (Above)

If natural pasture, cut and carried, where from?

1. Own farm
2. Others' farms

3. Road side
4. River banks

Are the kids fed differently from adult goats? If yes, how are they fed?

1. Tethered

2. In a pen

3. Free grazing at the compound

At what age kids let out to graze?

1. 1 month
2. 1.5 months
3. 2 months
4. 2.5 months
5. Over three months

Do you take any measures to control worms? If yes in which animals?

1. All animals
2. Local breeds
3. Exotic
4. Cross

Are young kids protected? yes..... No.....

What drugs (Dewormers) do you use?

If you deworm goats, when did you begin?

1. 1 year ago
2. 2 years ago
3. 3 years ago
4. 4 years ago
5. 5 years ago
6. 6 years ago
7. More than 6 years ago

When did you deworm last?

1. This month
2. 3 months ago
3. Half an year ago
4. 1 year ago
5. 2 years ago
6. 3 years ago
7. 4 years ago
8. 5 years ago
9. 6 years ago

Which animals did you deworm in the wet season?

1. All animals
2. Goats
3. Local
4. Exotic
5. Crosses

Which animals do you deworm in dry season? (Above)

Do you have other diseases that you treat for?

If so, which ones and what drugs do you use?

1. No. of kids born from August/September to the time of the interview
2. No. of kids died at ≤ 3 months of age from the period March/April to the time of the interview
3. No. of kids died at ≤ 3 months
4. No. of kids died at ≤ 3 months

Do you use fertilizers on the pastures? If so, which ones?

What courses or demonstrations pertaining to livestock have you attended?

5. In the dry season

Where are they mated? **Part two**

Total flock (M+F)

Total number of males

Adult males castrated

Entire adult males

Adult females pregnant

Adult females non-pregnant

Females below puberty

Adult females ($>8-9$ months age)

*1 Number of animals (M+F) below puberty

*2 Number of kids (<3 months old)

No. of kids born from March/April to the time of the interview

No. of dead kids in the period Feb.-march to time of interview

No. of kids born from August/September to the time of the interview

No. of kids died at ≤ 3 months of age from the period March/April to the time of the interview

No. of kids died at ≤ 3 months

When do female goats come on heat?

- | | |
|-----------------------------|-------------------------|
| 1. One animal every 2 weeks | 2. One animal per month |
| 3. 2 animals in one month | 4. In the wet season |
| 5. In the dry season | |

When are they mated once on heat?

1. 1st day when they show heat signs
2. 2nd day after they show heat signs
3. 3rd day after they show heat signs

When do you put the females together with the males?

- | | |
|------------------------|--------------------|
| 1. Never | 2. Once a month |
| 3. Once every 2 months | |
| 4. Once every 3 months | 5. Always together |