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Chapter

The Interactions of Some Minerals Elements in Health and Reproductive Performance of Dairy Cows

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Abstract

The dairy business is recognized as an important economic and nutritional resource. The food and agriculture organization (FAO) estimates that there are about 245 million dairy cows in the world. Milk production offers enormous health, sociological, and economic benefits around the world. In emerging economies, livestock serves a range of purposes, including providing a source of household income, a financial asset for women, food security, risk management, and a direct connection to human health. With a total value of $628.27 billion USD in 2018, the dairy industry provides a major economic impact. The dairy business supports over a million employment, either directly or indirectly. In terms of public health, the dairy business plays a role. While dairy products are a beneficial part of a balanced diet, zoonotic and food-borne diseases originating in dairy animals can be dangerous to humans. Milk production performance in emerging countries is poor. Non-infectious infertility in dairy cattle is most commonly caused by energy, protein, and mineral deficiencies. According to the current review, minerals play an essential role in animal production and reproduction issues. This chapter discusses the linkages of several mineral elements in health and reproductive performance that affects the dairy industry.

Keywords: minerals, health, reproductive performance, dairy cows

1. Introduction

Ruminants, like all other animals, must receive all the essential dietary nutrients, including water, protein, carbohydrates, fats, minerals, and vitamins in optimal amounts to maintain health, growth, and to reproduce at their potential levels. Climatic factors may modify the amount of certain nutrients that animals require and affect the responses to adequate diets. The responses to supplements will depend upon whether other essential nutrients are adequately supplied and whether animal management practices will allow responses. For example, feeding mineral supplements to cattle will not increase growth if protein energy is lacking [1, 2].

Mineral deficiencies and imbalances for herbivores are reported for almost all tropical regions of the world [3, 4]. Many reports from Africa, dating back to the
early part of this century, have revealed the beneficial effects of minerals supple-
mentation on the overall performance, performance calving percent, and reduce
mortality.

Grazing livestock does not usually receive mineral supplementation except for
common salt and must depend almost exclusively upon forage for their mineral
requirements, only rarely; however, can tropical forages completely satisfy all
mineral requirements. Deficient levels of certain elements were noted for many
forages in the world. Mineral deficiencies in soil and forages have long been held
responsible for low production and reproduction problems among grazing tropical
cattle. Plants withdraw essential elements from the soil solution in quantities to
satisfy their own requirement as well as satisfy many of the requirements of grazing
livestock. Besides essential plant elements, plants also withdraw Selenium (Se),
Cobalt (Co), and Iodine (I) which are essential for the grazing ruminants. The soil-
plant relationship is direct in that the plant must obtain all the mineral nutrients
from the specific soil with which it has contact.

At least 16 minerals, elements are nutritionally essential for ruminants. There
are 7 macro-elements, therefore, Calcium (Ca), Phosphorus (P), Sodium (Na),
Chloride (Cl), Magnesium (Mg), Potassium (K) and Sulfur (S), and 9 trace
or micro-elements, Iron (Fe), Iodine (I), Zinc (Zn), Copper (Cu), Cobalt (Co),
Molybdenum (Mo), Manganese (Mn), Selenium (Se) and Florine (F). Others pos-
sibly required, based on limited evidence, are aluminum (Al) arsenic (As), Boron
(B), bromine (Br), Cadmium (Cd), Lithium (Li), Nickel (Ni), Lead (Pb), tin (Sn),
Vanadium (V), Silicon (Si) and Chromium (Cr).

Cattle play an important role in the livestock economy. The low performance of
milk production and reproductive problems are common causes of profit loss to the
farmers. During an animal’s lifetime, a longer dry period and fewer calving’s and
lactations result in significant economic losses. Reduced calf crops hamper selection
efficiency in long-term dairy herd improvement, whereas infertile animals result in
a direct loss of milk production [5].

Minerals, in addition to energy and protein, play an important role in animal
production and reproduction. Mineral deficiencies can create reproductive prob-
lems in livestock since minerals are essential for their health and reproduction.
Infertility and reproductive abnormalities in our livestock herd have become a
major issue. Both macro and trace minerals are essential for the synthesis of struc-
tural components of the body as well as the appropriate functioning of enzymes,
hormones, vitamins, and cells. Mineral insufficiency and toxicity are localized
problems. Minerals can have a positive or negative impact on an animal’s physiologi-
cal well-being, depending on the situation.

Approximately 5% of the body weight of an animal consists of minerals. Inve-
vestigations have shown that ruminant livestock may deteriorate and fail to
achieve a responsible level of productivity because of deficiencies and excesses of
minerals in soils and plants. Furthermore, such deficiencies or excesses may give
rise to problems of reproduction and to clinical signs indicating minerals defi-
ciences, such as wasting diseases, loss of hair, depigmented hair, skin disorders,
non-infectious abortion, diarrhea, anemia, loss of appetite, bone abnormalities,
tetany, low fertility, and pica [6, 7]. Soil fertility is defined as the ability of soil to
supply proportionate and sufficient nutrients and water to plants [8, 9].

Minerals in the ration of dairy animals are important for regulating biological
activities, growth, production, and reproduction. However, animals are ingesting a
little quantity of minerals through feeds and fodder in the tropical climate. Also, soils
from all over the country are getting depleted for one or more mineral elements in
soil, plants, and animals [10]. In dairy buffaloes, the average intake of zinc was higher
by 72.5% than National Research council (NRC) requirements for dairy cattle. The
average intake of copper was higher by 40% than National Research council (NRC) requirements. Increasing Cu intake decreased postpartum uterine involution and ovulation intervals ($r = -0.31, -0.32; P < 0.01$). Intake of Zn and Cu have favorable effects on various reproductive parameters and blood levels of macro-minerals [11].

Micronutrients, particularly mineral elements are inevitable for the normal metabolic and physiological processes of animal systems. The importance of minerals in regulating biological systems, growth, production, and reproduction is well documented [12, 13]. Hence, dairy cows depend on forages for their mineral requirements [14]. Garg et al. [15] and [16] both found high rates of forage and blood serum samples with Cu and Zn levels below the threshold levels. Cu and P deficiencies were found in fodder samples collected from the pasture by Miles and McDowell [17]. Cu, Zn, P, and S levels in soil, vegetation, and dairy cows have been decreased across the country [10]. The quantity of minerals, thus, present in forages may not be sufficient for optimum growth, milk yield, and reproduction when those were fed to dairy cows [14].

Macro minerals and trace minerals are equally important as they take part in the formation of the structural component of the body and the proper functioning of enzymes, hormones, vitamins, and cells [18].

Minerals are structural components of the body and play an important role in enzymes, hormones, body fluids, and tissues, as well as cell replication and differentiation regulators. Minerals are necessary for all animal physiological activities, including reproduction [19].

2. Minerals physiology

It must be realized that there are two categories of trace elements action: physiological and pharmacological. A trace element acts as an essential nutrient by preventing or reversing a deficiency, no effect is apparent when supplementation is given to an organism that is not deficient; this action is described as pharmacological. In contrast, the pharmacological action of an element is independent of the nutritional status [20].

2.1 Calcium (Ca)

Major Functions are bone and teeth formation; nerve function; muscle contraction; blood coagulation, cell permeability, essential for milk production. Absorption takes place in the duodenum by active and passive absorption (diffusion). Vitamin D required and the ratio of Ca:P is important. Excretion by feces as a major path, the urinary loss is minimal. Vitamin D involved in absorption & bone deposition; excess P and Mg decrease absorption; Ca:P ratio should not be below 1:1 and over 7:1 (1:1 to 2:1 for monogastric) [21].

2.2 Phosphorus (P)

The major functions are bone and teeth formation, phosphorylation, high energy phosphate bonds, Po; important in acid-base balance, a component of RNA, DNA, and several enzyme systems [2, 22]. Approximately 20% of the phosphorus content of the body is outside the skeleton, and less important function, occurring in nucleo-protein, ATP and other energy-rich compounds, energy and intermediate of carbohydrates metabolism [23, 24]. Absorption takes place in the duodenum, vitamin D is required, and a ratio of Ca: P (1:1) is important. Excretion through feces as a major pathway, and urine from a high concentration diet. Excess calcium and magnesium decrease P absorption [25].
2.3 Cobalt (Co)

Rumen microorganisms use cobalt for the synthesis of vitamin B$_{12}$ and the growth of rumen bacteria, components of adenosylcobalamin and methylcobalamin [22, 26–28]. Absorption as part of vitamin B$_{12}$, absorbed in the lower portion of the small intestine. Excretion mainly through feces, urine, and around 1–12% could be via milk [29].

2.4 Copper (Cu)

It is a co-factor in several oxidation-reduction enzyme systems such as hemoglobin synthesis, bone formation, maintenance of myelene of nerves, and hair pigmentation [30–34]. Absorption, principally in the small intestine, in ruminant only 1–3% of copper absorbed [35–37]. Excretion, via feces is the major route [38–40]. The dietary content of components known to reduce the availability of Cu, e.g. S, Mo, Zn, Cadmium, Fe or soil have been reported. The inorganic sulfate potentiate the adverse effect of Mo on the utilization of Cu by sheep [41–43].

Molybdenum does not interfere with Cu transport to the liver, but interferes with the synthesis of the plasma enzyme ceruloplasmin, the resultant apoceruloplasmin-like substances, with fewer Cu atoms per molecule and less enzyme activity, are catabolized more rapidly than hob-ceruloplasmin [38]. Pope [44] indicated that levels of forage Mo as low as 2, 0 ppm can be antagonistic to Cu metabolism. The inclusion of 10% of 3 diverse soils in the diet of sheep reduced the coefficient of true absorption for Cu by at least 50% [45]. Dick [46] in experiments with sheep receiving 30 mg Cu/day found that diets containing about 90 gm calcium carbonate/kg halved the hepatic retention of Cu. Campbell et al. [47] showed that liver Cu reserves in calves at pasture were depleted by a daily dose of Fe. Mills and Dalgarano [48] found that cadmium at 7 mg/kg added to the diet of the pregnant ewes reduced the liver-copper stores of her offspring. Consumption of rations containing 40, 220, or 420 mg Zn/kg reduced the fraction of dietary Cu retained by the liver of growing lambs [49].

2.5 Manganese (Mn)

It is essential for normal bone formation, activator and constituent of the enzyme systems, involved in oxidative phosphorylation, amino acids metabolism, and fatty acid synthesis [50–52]. In vitro experiments have shown that Mn in plasma became bound to two proteins, to $\alpha_2$-macro-globulin, in its divalent Mn$^{2+}$ state and to transform in its trivalent Mn$^{3+}$ state [53].

Most of the pathological changes that developed appear to be related to defective synthesis of mucopolysaccharides and glycoproteins and probably reflects the importance of the role of Mn in several glycosyl-transferase enzymes involved in their synthesis [54].

Absorption, is throughout the small intestine [55, 56] (Watson et al., 1973). Excretion, via feces with very small amounts in urine [57, 58]. Excess calcium and phosphorus decrease Mn absorption [2, 59].

2.6 Zinc (Zn)

It is a component or co-factor of several enzymes, including peptidase and carboxylic anhydrase, needed for bone and for normal protein synthesis and metabolism (Prask and Plocke, 1971; Mills et al., 1967).
In dairy buffaloes, the average intake of zinc was higher by 72.5% than NRC requirements for dairy cattle. The average intake of copper was higher by 40% than National Research council (NRC) requirements. Increasing Cu intake decreased postpartum uterine involution and ovulation intervals \( r = -0.31, -0.32; P < 0.01 \). Intake of Zn and Cu have favorable effects on various reproductive parameters and blood levels of macro-minerals [11].

A sensitive response to zinc intake is exhibited by the activity of the alkaline phosphatase of serum and bones, and by the activity of the pancreatic carboxypeptidase A, and perhaps by the biopotency of insulin [60, 61] (Kirchgissner et al., 1976b; Roth et al., 1974).

Absorption takes place in the rumen and small intestine [62–64]. Excretion is via feces, and small amounts in urine [65–68]. Miller et al. [69] strongly suggested that endogenous fecal losses of zinc are influenced by the nature of the diet and greatly reduced when zinc intake is low. Estimates of urinary Zn passes ranged from 0.004–0.019 mg/kg liver weight/day for cattle [70].

2.7 Magnesium (Mg)

Essential for normal skeletal development, as a constituent of bone; enzyme activator, primarily in the glycolytic system, helps to decrease tissue irritability. Absorption Throughout digestive tract, major site reticulorumen. Excretion via urine, feces & milk, urine major pathway. Sources are Magnesium oxide, Magnesium sulfate, Magnesium chloride, Magnesium carbonate. Interrelationships and toxicities are excess upsets Ca and P metabolism; toxicity not likely [21].

2.8 Iron (Fe)

Body Fe content is approximately 3–4 g, which almost corresponds to a concentration of 40–50 mg of Fe per kilogram of body weight [71]. The majority of Fe in the body is contained within hemoglobin [72]. Fe is an essential component of myoglobin [73]. Fe is also necessary for growth, development, normal cellular functioning, and synthesis of some hormones and connective tissue [72, 74, 75]. Absorption throughout the gastrointestinal tract, major sites are duodenum and jejunum. Excretion by feces, urine, sweat, and hair, hemorrhage can be a major loss. Sources are ferrous sulfate, ferrous carbonate, leafy plants, meats, legume seeds, and cereal grains. Cu is required for proper Fe metabolism. Too much Fe may be deleterious interfering with P, Cu, and Se [21].

3. Mineral sources

3.1 Forages

Only, rarely, can tropical forages satisfy all mineral requirements [76]. Feedstuffs of plant origin are generally poor in minerals. The commonly used fodder, cereals, cereal by-products, and vegetables derived concentrates do not contain sufficient minerals to meet the optimum requirements of farm animals [77, 78]. Mineral element concentrations in forages are influenced by a variety of factors, including soil, plant species, maturation stage, yield, pasture management, and climate. The impact of soil chemistry and features on the emergence of mineral issues in grazing ruminants has been studied [51, 58, 79]. Plants withdraw essential elements from the soil solution in quantities to satisfy their own requirement. Besides essential plant elements, plants also withdraw selenium (Se), Cobalt (Co), and Iodine (I), which are essential for the grazing requirements.
It is generally accepted that the herbs and legumes are richer in several mineral elements than grasses. As the plant matures mineral contents decline due to the natural dilution process and translocation of nutrients to the root systems.

In most circumstances the concentrations of phosphorus P, K, Mg, Na, Cl, Cu, Co, Fe, Se, Zn and Mo, decline as plants mature. Forage Ca concentrations is less affected by advancing maturity [2, 80].

Climate as well as forage management and yield influence plant mineral composition. In Africa, uncontrolled heavy grazing pressure causes many palatable genera to disappear and to be replaced by high lignified species. Grazing pressure also changes the leaf/stem ratio radically, therefore having a direct bearing on the mineral content of the plant. Increasing crop yield removes minerals from the soil at faster rates. Over liming can accumulate Se or Mo toxicity in livestock by increasing plant concentration of these elements [58].

Bhanderi et al. [81] discovered that the phosphorus level in concentrate ingredients was high (0.32–0.67%) but low in dry roughages (0.06–0.20%). Copper was abundant in greens (12.31 ppm). The zinc content of wheat straw was found to be low (19.71 ppm), but it was high in manganese (47.88 ppm) and iron (630.24 ppm). Cobalt was detected in abundance in lucerne and chikori green (<0.35 ppm).

Copper (Cu) content was found below the critical level (<8 ppm) in all types of straws and concentrate ingredients, except cottonseed cake. Zinc (Zn) content was below a critical level (<30 ppm) in all the straws except paddy straw. Greens and cakes were found to be a better source of Zn as compared to crushed grains. The Mn levels in the district ranged from 36.47–478.12 ppm in straws, 62.64–132.99 ppm in green fodders, 13.18–75.74 ppm in concentrate ingredients. These findings are in agreement with the observations of Youssef et al. [82], Yadav et al. [83], and Mandal et al. [84]. Cobalt content in feed and fodder resources was found in the range of 0.18 ppm to 0.71 ppm. Concentrates and roughages contained 0.25–0.67 and 0.06–0.20% P, respectively.

Ruminant production in different regions of the world are depends on forages to satisfy all their nutritional requirements. Forage and soil mineral imbalances are common, and forages are frequently low in essential trace minerals [14, 85].

Mineral shortages, such as those of the major elements Ca, P, Mg, Na, S, and the trace elements Co, Cu, I, Mn, Se, and Zn, can impact the output of grazing animals at pasture in most parts of the world [86–92].

The nutrition of grazing animals is a complicated interaction of soil, plant, and animal. Forage Cu\(^{2+}\) concentrations were found to be sufficiently high to meet the demand of animals (8 mg/kg) during both seasons (winter and summer) [34]. Forage Co\(^{2+}\) levels were deficient for ruminants during both seasons because these were lower than the critical level [93]. Except for P and Cu, Co\(^{2+}\) insufficiency is the most common mineral deficiency in grazing animals [94]. Plant absorption of Co\(^{2+}\) is influenced by soil Co\(^{2+}\) and Mn\(^{2+}\) concentrations. Mn\(^{2+}\) deficiency in the soil reduces Co\(^{2+}\) uptake in forages. High levels of Mn\(^{2+}\) were observed in the soil in this study, which could have resulted in reduced Co\(^{2+}\) absorption by plants and, as a result, low levels in plant tissues. McKenzie [95, 96] claims that soils with high levels of manganese oxide bind free soil Co\(^{2+}\) to their surfaces, resulting in reduced Co\(^{2+}\) availability to plants. Low Co\(^{2+}\) concentration of soil was also a possible explanation of the high level of Mn\(^{2+}\) in forage as these elements antagonize the soil [95, 96]. Several factors including soil, plant species, pasture management, and climate, may affect the likelihood of Zn\(^{2+}\) deficiency in ruminants. Cox [97] reported the low level of Zn\(^{2+}\) in soil and plants. Plant maturity has also been reported to affect Zn\(^{2+}\) concentration of forage [31, 98–100].

The mineral composition of plants also termed the ionome [101], is an integrated outcome of interactions between endogenous plant processes and the
environment [102]. Leaf mineral composition, the leaf ionome, reflects the complex interaction between a plant and its environment including local soil composition, an influential factor that can limit species distribution and plant productivity. Land plants require several inorganic mineral nutrients that they must take up from the soil solution into roots and partition appropriately within the plant [103–105].

Kitchell (1963) reported an average Co concentration of 0.11 ppm in dry matter in mixed pasture herbage, and mean Co levels of 0.10, 0.20, and 0.26 in the hay by Zacherl et al. [106], Schiller et al. [107], and Kocialkowski et al. [108]. Grassland grasses have a lower Co concentration than legumes, while legumes have a greater Co level [109–111]. As a result, if legumes are present in the forage, animals are less prone to acquire Co deficiency. Cereal grains, especially maize, are poor suppliers of Co, with concentrations typically ranging from 0.01 to 0.06 ppm. Wheat bran contains 0.12 to 0.16 ppm, while leguminous seed and oilseed meals contain 0.2 to 0.3 ppm Co [58].

A pasture’s various plant varieties provide grazing animals with a reliable source of mineral nutrients. Ruminant production is hampered by an insufficient supply of mineral nutrients. A proper analysis of the mineral levels in the animal body, forages, and soil is required to determine whether animals have an acceptable requirement for mineral nutrients. Although grazing livestock obtains its mineral requirements through forages, they are unable to fully meet the demands of animals in terms of mineral elements [3].

Co levels in forage varied from 0.42 to 0.60 mg/kg. These levels, however, were higher than the threshold level of 0.01 mg/kg [34]. The amounts of forage Co discovered in our study were greater than those previously reported by Khan et al., [112] and Espinoza et al. [113]. Co deficiency has been observed to be the most limiting factor for animals grazing in various areas.

Mn concentrations in forage ranged from 153.43 to 215.20 mg/kg. According to McDowell, all mean Mn readings were over the threshold limit of 20 mg/kg [4]. These values for ruminants were higher than those found by previous studies [114] in various parts of the world. These values, however, are within the range reported by Pastrana et al. [115].

3.2 Soil

In some cases, a soil assessment might reveal the presence of important minerals deficiency in animals. Soil concentrations of Co, Mo, and I reflect the plants’ concentrations of these elements to a certain degree. However, several factors affect forage mineral uptake from the soil, including, the yield of the plant, stage of maturity, species and strain deficiencies, climatic and seasonal conditions, chemical forms of minerals, and factors of the soil, including pH and degree of aeration and water logging. Soil analysis though useful for pasture fertilization has been eliminated in some investigations because of its direct relationship to the mineral content of herbage growing on the soil (Gitter et al., 1975). For instance, a plant growing on cobalt-deficient soil may not necessarily be deficient in Co, nor would a soil rich in Co necessarily yield plants with high levels of Co (Lattuer, 1983). However, in the Netherlands, soil analysis is preferred to that of forage analysis to establish a cobalt deficiency [116].

Hartmans [117] reported that the availability of Cu in the soil does not show any positive relationship with the Cu status of the animal. Data from Brazil, Bolivia, Guatemala, Malawi, and Florida (USA) have indicated that mineral correlation among soil, plant, and animal tissue concentration was highly variable among locations, and are often low and nonexistent [4].

The soil was deficient in P. The overall mean concentration of P (9.42 ± 0.59 ppm) in soil, whereas, in plants the overall mean of P (2913 ± 470 ppm). The dairy cattle
blood serum was found to be deficient in P. Overall incidence (%) of deficiency in cattle blood serum was found to be 74.50% in P. The incidence of deficiency in cattle blood serum was found to be above 70%. In cattle blood serum, P (2.90 ± 0.380 mg/dL). A significant positive correlation was found between plants and cattle for P [118].

Productive and reproductive performance of dairy cattle is mainly dependent on their nutritional status. Here, the role of soil and the nutritional quality of plants plays a very important role. Animals are malnourished particularly with regards to lack of micro and macro mineral of soil, and feed. The availability of minerals in soil depends upon their effective concentration in soil which is influenced by pH, moisture, organic matter, leaching, and the presence of other elements [119, 120]. The concentration of minerals in plants is affected by the soil-plant interaction, pH, species, stage of maturity of plant, etc. [2]. There appears to be a definitive role of minerals deficient soil to cause deficient levels in feeds (McDowell and Conrad, 1990).

The concentrations of some trace minerals varied greatly among seasons and sampling periods. Seasonal effects were found in all soil microminerals except zinc, while forage iron, zinc, and selenium were affected by seasonal changes. All soil mineral levels except cobalt and selenium were sufficiently high to meet the requirements of plants for normal growth during both seasons (winter and summer). During the summer, forage Zn levels were marginally insufficient, but all other forage micro-minerals were within the necessary range for ruminants in both seasons. Although fodder microminerals were within the range required by ruminants, they were not high enough to prevent ruminant predisposition to nutrient deficiency-related illnesses.

Soil materials high in clay were highest in all analyzed elements Speirs et al., 1989). The overall range for cobalt in soils on a worldwide basis is 0.1–70 ppm [98] and the average amount is 8 ppm [121].

Mean copper contents for uncontaminated soils worldwide range from 13 to 24 ppm, but the overall range for world soils is higher (1–140 ppm) depending on the nature of the soil parent materials [98]. Mn levels in world soils range from 7 to 9200 ppm, with an estimated grand mean of 437 ppm [98]. Manganese is found in soils and minerals mostly as Mn²⁺, Mn³⁺, and Mn⁴⁺ [98, 122] but only Mn²⁺ is absorbed by plants [121]. The overall zinc content of soils ranges from 10 to 300 ppm [121].

Co deficiency in ruminants is relatively widespread, resulting in loss of appetite, progressive emaciation retarded sexual development, muscular atrophy, or anemia. Sometimes the only symptom may be very slow growth or none. It has been shown that vitamin B₁₂ is synthesized in the rumen by micro-organisms, hence the ruminant’s special requirements for dietary Co. The average content of Co in the lithosphere has been estimated to be about 40 ppm and the total Co content of soils is usually in the range of 1–40 ppm (Almond [123], Hawkes [124], Swaine [125]). Many pasture soils in different parts of the world are known to have too low a Co content. However, many instances of Co deficiency have been reported from soils of 2–5 ppm or less of total Co (Bear [126], Stewart [127], Sullivan [128], Young). The level of deficiency lies about 0.25 ppm in mineral soils [129].

The average occurrence of Cu in the earth’s crust has been estimated to be 70 ppm and its total content in soils ranges usually from about 2 to 100 ppm have been reported (Muff [130], Layering [131], Mitchell [132], Vogt). The content of Cu in most normal plants is usually within the range of 5 to 25 ppm but varies with plant parts and species, state of maturity, soils, etc. Bear [126] gives average Cu plant contents varying from 12 to 20 ppm.
The typical Mn content in the lithosphere is 1000 parts per million, whereas total Mn concentrations in soils range from less than 100 to several thousand parts per million. The total Mn concentration of the soil, on the other hand, cannot be used to predict the availability of this element to plants due to many factors that influence uptake. Among the factors affecting Mn availability, soil pH and the oxidation-reduction conditions may be the most important since the forms in which Mn occurs in soils are strongly related to these factors.

The lithosphere’s Zn content has been estimated to be around 80 ppm, while total Zn content in soils has been recorded to range from 10 to 300 ppm, with occasional lower and higher levels. However, because of various factors impacting Zn availability to plants, the total level of Zn in soils has been found to be an inconsistent indicator of soil Zn status. Zn shortage can occur in a variety of soil textures, but it is most common in sandy soils. Viets et al. [133] found that Zn is more readily available in acidic soils than in alkaline soils. Zn content in plants typically ranges between 20 and 100 ppm dry weight, however it varies by plant species and plant sections. Plant maturity, the nature of the soil in which it grew, meteorological circumstances, and, of course, Zn fertilizer all have an impact on the Zn content of plants.

The effects of sample times on soil Co, Fe, and Mn were not significant. In this study, all mean soil Fe and Mn values were higher than the requirements of forage crops, whereas the opposite was true for soil Co. The influence of sample times on forage Fe and Co was found to be non-significant, however, forage Mn showed a constant increase in forage Fe and a drop in Co and Mn with sampling time. From this pattern of nutrient transfer from soil to forage, a toxic range of these nutrients is possible for the animals at any time during the year.

The soil was deficient in P. The overall mean concentration of P (9.42 ± 0.59 ppm) in soil, whereas, in plants the overall mean of P (2913 ± 470 ppm). The dairy cattle blood serum was found to be deficient in P. Overall incidence (%) of deficiency in cattle blood serum was found to be 74.50% in P. The incidence of deficiency in cattle blood serum was found to be above 70%. In cattle blood serum, P (2.90 ± 0.380 mg/dL). A significant positive correlation was found between plants and cattle for P [118].

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Analysis of variance shows the non-significant effect of sampling periods on soil Co concentration. Mean soil Co concentrations varied from 0.665 to 0.789 mg/kg during all sampling intervals. All mean soil Co values were higher than the critical level of 0.1 mg/kg as described by McDowell et al. [17].

Soil Mn concentration values ranged from 54.75 to 69.38 mg/kg. These levels, however, were higher than the essential limit of 5 mg/kg proposed by Rhue and Kidder [134]. Similar soil Mn concentrations were observed by Prabowo et al. [135]. The current study’s results, however, were lower than those reported by Espinoza et al. [113].

4. Mineral elements requirements

No organism can attain its full potential of growth and performance unless its requirements for all essential nutrients are met. Variation in the composition of the body and its secretion and in the absorption of an element from the gut presents problems in terms both of the amount of basic information needed to give reliable mean values and of allowing for the variation in dietary requirements of different animals in specific productive status [22, 136].

The following minerals are known to be required by one or more animal species for a normal life, processes, Co, I, Fe, Cu, Zn, Mn, Se, Cr, F, Mo, and Si [80, 137]. Other possibly required based on limited evidence are aluminum (Al), arsenic (As), boron (B), bromine (Br), cadmium (Cd), lithium (Li), nickel (Ni), lead (Pb), tin (Sn) and vanadium (V). These elements are referred to as newer trace elements [2, 138–140]. Inadvertent high soil ingestion is favored when soil has a weak structure and poor drainage, high stocking rate, high earthworm population, and during months when pasture growth is poor [2, 141]. Rosa [142] reported that the inclusion of 10% costa Rican soil in the diet of sheep decreased apparent and true phosphorus absorption. Mertz [143] illustrated that soil is a very important source of trace elements, as well as iron (Fe). Fonseca and Lang (1976) reviewed that Mn accumulation by plants was dependent upon soil PH.

Langlands et al. [144] studied the effects of stocking rate and soil ingestion on Cu and se status of grazing animals, it was concluded that both Fe and Cu concentrations in the tissues of grazing sheep may be decreased when stocking rate is increased. Suttle et al. [45] conclude that the Co antagonists Mo and Zn are biologically available in the soil and their ingestion from soil contamination of herbages may be a factor in the etiology of hypocuprosis.

In temperate areas, frequent glacial coverings removed the older soils, and in the early stages of rock washing to the soil, there was continued slow release of soluble ions [145, 146]. Young and alkaline geological formations are generally more abundant in most trace elements than the older, more acid, coarse sandy formation [117] Dutoit et al. [147] in South Africa performed soil and herbage analysis, and also used cattle blood as an indication.

All elements present a lower concentration than 50 mg/kg body weight, on average, maybe called trace elements. For trace elements to be essential, too low a
concentration in food must result in deficiency symptoms that can be prevented or cured by dietary addition of this element [148, 149]. All elements known to participate as activators or components of enzymes in biochemical reactions and to be deeply engaged in metabolic functions are considered essential [150].

Many factors affect mineral requirements including nature and level of production, age, level and chemical form of elements in the feed ingredients, interrelationship with other nutrients, supplemented mineral intake, breed, and animal adaptation [151, 152].

Adequate intake of forages by grazing ruminants is essential to meet mineral requirements. Factors that greatly reduce forage intakes such as low protein (> 7.0%) and energy content and increased degree of lignification, likewise reduce the total mineral consumed [2].

The dietary requirement of P for lactating cows with milk yield 20 kg/day was 44–51 g/day. The dietary requirement of P for lactating ewes with milk yield 3 kg/day and live weight 40 kg was 3.7 g/day, and for sheep at 13 weeks of pregnancy and live weight 40 kg was 1.4 g/day [22]. For lactating cows of 500 kg live weight and 20 kg milk/day, the net requirement for Cu was 5.5 mg Cu/day, and the dietary requirement was 138 mg Cu/day, and the relative requirement was 8–11 (19.2–15.2) mg Cu/kg diet dry matter. For lactating ewe of 75 kg live weight and 3 kg milk yield, the net requirement was 1.24 mg Cu/day, and the dietary requirement was 20.7 mg Cu/day.

The Co dietary requirement of sheep and cattle fed pasture diet was 0.08–0.11 mg/kg DM. 0.08 mg regarded as marginal, 0.11 mg as adequate. The requirement for Zn will be fully met by rations providing approximately 30 mg Zn/kg DM [22].

The requirements of Mn for growth may be rations providing 10 mg/kg DM, about 20–25 mg/kg DM is needed to permit optimum skeletal development. Experimental results so far available suggested that this should be adequate to meet requirements for reproduction [22]. Table 1 showed some mineral requirements and critical level for ruminants [2].

National Research council (NRC) [153] has recommended for dairy cattle the level range from 0.3 to 0.4%. Increasing the concentration of dietary phosphorus above the requirement (more than 0.38–0.40%) does not improve reproductive performance [154].

Depending on the stage of lifecycle and dry matter consumption, the required Zn dietary value for dairy cattle is normally between 18 and 73 ppm. Cu, Cd, Ca, and Fe interact with Zn metabolism and limit its absorption [18]. Dairy cows require 40 parts per million of zinc in their diet [153]. The maintenance requirement for absorbed Mn was defined at 0.002 mg/kg of body weight, whereas the growth requirement was set at 0.7 mg/kg of growth, pregnancy at 0.3 mg/d, and lactation at 0.03 mg/kg of milk [153]. Cattle may require up to 50 mg of Mn/Kg of DM during pregnancy because it aids in skeletal cartilage growth and fetal bone formation [155]. A cobalt deficiency ultimately resulted in vitamin B12 deficiency. Manganese, Zinc, iodine, and monensin may reduce cobalt deficiency. The dietary requirement for a lactating cow is 0.11 ppm of the ratio of dry matter intake (Balamurugan et al. [18].

Depending on the stage of lifecycle and dry matter consumption, the required Zn dietary value for dairy cattle is normally between 18 and 73 ppm. Cu, Cd, Ca, and Fe interact with Zn metabolism and limits its absorption [18]. Dairy cows require 40 ppm of zinc in their diet [153]. The maintenance requirement for absorbed Mn was defined at 0.002 mg/kg of body weight, whereas the growth requirement was set at 0.7 mg/kg of growth, pregnancy at 0.3 mg/d, and lactation...
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Cattle may require up to 50 mg of Mn/Kg of DM during pregnancy because it aids in skeletal cartilage growth and fetal development.

5. Roles of minerals in health

Clinical signs of mineral deficiencies in animals gave a good indication of the mineral status. Alopecia, parakeratosis, hair discoloration, weakness, and fertility were the major clinical signs at the different locations. In this study, Zn deficiency symptoms reported by Pallauf and Kirchgessner [156]; Kirchgessner et al. [60, 61], and Schhwarz and Kirchgessner [157], were low growth, weight loss, alopecia, and sever parakeratosis. Idris et al. [1] observed that clinical signs of Cu deficiency were anemia, stunted growth, hair discoloration, infertility, and diarrhea. Impaired growth and poor reproductive performance were the most significant features of Mn deficiency in ruminants [22, 54, 56].

All the diseases recorded in the farm health records were reported. Type of veterinary health care, cow calendar, vaccination program, and clinical signs of mineral deficiencies for each survey were also reported. Repeat breeder’s percent, average calving interval, average conception rate, percent and age of delayed puberty heifers, and average milk yield for each survey were reported. As stated by Underwood (1983), changes in an animal’s appearance or level of production can often be early identification of diet inadequacy. Severe or acute deficiencies of minerals are often characterized by specific clinical signs, but disorders are often mild or marginal, expressed only as vague unthriftiness, or suboptimal growth, fertility, or productivity. These changes are often non-specific and indistinguishable from those resulting from inadequate energy, protein, or vitamins, or from parasitism, or toxic plants. Therefore, it often becomes necessary to resort to chemical analysis in order to adequately determine mineral insufficiencies (Underwood, 1983).

In fact, approximately 5% of the bodyweight of an animal consists of minerals. Investigations have shown that ruminant livestock may deteriorate and fail to achieve a responsible level of productivity because of deficiencies and excesses of minerals in soils and plants. Furthermore, such deficiencies or excesses may not only result in low production but may give rise to problems of reproduction and to clinical signs indicating minerals deficiencies usually encountered worldwide, such as wasting diseases, loss of hair, depigmented hair, skin disorders, non-infectious abortion, diarrhea, anemia, loss of appetite, bone abnormalities, tetany, low fertility and pica [6, 7].

A dietary deficiency of either Ca or P is sufficiently prolonged, however, results in skeletal abnormalities, subnormal growth, deprived appetite, rickets, and

<table>
<thead>
<tr>
<th>Elements</th>
<th>Animal requirements</th>
<th>Tissue</th>
<th>Critical levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dairy cows</td>
<td>beef cattle</td>
<td>sheep</td>
</tr>
<tr>
<td>P</td>
<td>0.34</td>
<td>0.17-0.59</td>
<td>0.36</td>
</tr>
<tr>
<td>Ca (ppm)</td>
<td>10</td>
<td>3–10</td>
<td>0.38</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>40</td>
<td>20–50</td>
<td>7–11</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>40</td>
<td>20–40</td>
<td>20–40</td>
</tr>
<tr>
<td>Co (ppm)</td>
<td>0.10</td>
<td>0.05–0.10</td>
<td>30–33</td>
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Source: McDowell et al. [17]; McDowell et al. (1976).

Table 1. Mineral requirements and critical level for ruminants.

at 0.03 mg/kg of milk [153]. Cattle may require up to 50 mg of Mn/Kg of DM during pregnancy because it aids in skeletal cartilage growth and fetal development.
osteomalacia [23]. Uncomplicated Ca deficiency symptoms included hemorrhages and delayed coagulation of the blood (Martin, 1937; [13]). P deficiency in dairy cows resulted in a reduction in milk yield, loss of condition, depraved appetite, and temporary sterility [23, 158].

Zinc deficiency symptoms reported by Pallauf and Kirchgessner [156], Kirchgessner et al. [60, 61], and [157] were anorexia, low growth, weight loss, alopecia, severe parakeratosis, and epidermoid lesions [159, 160]. Apart from parakeratosis, the most characteristic consequence of Zn deficiency is the abnormal ossification of the skeleton, whereas poor ossification has been found in rats and growing pigs [161].

Copper deficiency causes anemia, stunted growth, bone deformation, change in hair color, infertility, diarrhea, enzootic ataxia or swayback in sheep, or fattening disease in cattle [1]. Mo-deficiency in cattle is characterized by intense diarrhea, and a change in coat color.

Mg deficiency is uncommon [162, 163]. The early and moderate symptoms of Mg deficiency include loss of appetite, nausea, vomiting, fatigue, tingling or numbness, rapid heartbeat, delirium, hallucinations, retention of sodium, low circulating levels of parathyroid hormone, and weakness [164–166].

The effect of cobalt deficiency in cattle and sheep are those of vitamin B12 deficiency and range from a mild deficiency with an ill-defined and transient thriftless with no clear clinical signs to moderate or severe deficiency with appetite failure, emaciation, and listlessness accompanied by characteristic pallor of the skin and mucous membranes caused by progressively increasing anemia [28] (ARC, 1989).

Impaired growth, development of skeletal abnormalities, poor reproductive performance, and ataxia of the newborn are the most significant features of manganese deficiency in ruminants [54, 56] (ARC 1989). Low Mn levels in the body (Mn deficiency) have been linked to hypercholesterolemia, impaired glucose tolerance, dermatitis, hair color changes, skeletal abnormalities, infertility, deafness, and impaired synthesis of vitamin K-dependent clotting factors [167–169].

Iron (Fe) is necessary for growth, development, normal cellular functioning, and synthesis of some hormones and connective tissue [72, 75]. In the case that the body supply of available Fe is too low, this led to a condition known as Fe deficiency. Fe deficiency causes an inadequate amount of hemoglobin to meet body’s oxygen transport needs. When the deficiency becomes severe, the condition is diagnosed as Fe-deficiency anemia [170, 171]. The most common symptoms of Fe-deficiency anemia are tiredness and weakness due to the inadequate oxygen supply to the body’s cells and paleness due to the decreased levels of oxygenated hemoglobin. The other symptoms include fatigue, dizziness, hair loss, twitches, irritability, impaired immune function, pagophagia, and restless legs syndrome [170, 172, 173].

6. Roles of minerals in reproductive performance

Minerals are required in reproductive processes because of their role in maintenance, metabolism, and growth [174]. Requirements for minerals are influenced by several factors that include age, stage of pregnancy, and stage of lactation [175]. Apart from energy and protein, mineral deficiencies such as calcium, phosphorus, iron, zinc, and copper have been reported to be a risk factor for placental retention [18], repeat breeding in dairy cows [176] (Kumar, 2014), abortion [177], and weak calf syndrome [177, 178]. Minerals are divided into two categories based on their requirements: macro minerals, which require more than 100 ppm in the diet and include calcium, phosphorus, magnesium, potassium, sulfur, sodium, and chloride; and micro minerals, which require less than 100 ppm in the diet and include...
calcium, phosphorus, magnesium, potassium, sulfur, sodium, and chloride. Trace or micro minerals, such as cobalt, copper, iodine, iron, manganese, selenium, and zinc, fall into this category and are required in amounts of less than 100 ppm in the diet [18].

Mineral deficiency has also been strongly associated with decreased reproductive performance in dairy cows. Inactive ovaries (anaestious) delayed sexual maturity and low conception rates have been reported when phosphorus intakes are low. Other minerals such as copper, manganese, and cobalt deficiencies have been associated with impaired ovarian function, silent anestrous and abortions.

Dekruif [179] illustrated that for optimal reproductive performance, cows must conceive within 80–85 days of calving. Ward et al. [180] illustrated that the calving interval is the best index for monitoring herd reproductive status. The calving interval is 477–523 days. Chantaraprakeep and Humbert [181] reported that a repeat breeder cow is a cow that inseminated more than three times and is still not pregnant.

For cattle, the female age at puberty are 6–10 months, the usual age at first service is 14–22 month, the length of the oestrus cycle is 21 days, the oestrus cycle type is polyestrous, the duration of oestrus is 18 hours, the gestation length is 280 days, and the first postpartum oestrus used for breeding is first after 42 days [182].

Many factors influence the amount of time between parturition and first oestrus in tropical cattle, including endocrine events, management, nutrition, heat and humidity, genetic-environmental interactions, illnesses, and internal and external parasites. Nutritional factors that result in reduced hemoglobin level (trace minerals deficiencies, and parasites infestation) also cause prolonged postpartum anoestrus and infertility [183].

Calving interval is taken as the best index for monitoring herd reproductive status [180]. According to chantaraprakeep and Humbert [181], a repeat breeder cow is a cow that is inseminated more than three times and still not pregnant. The normal gestation length is 280 days [182], and a cow with good reproductive performance would conceive within 80–85 days after calving [179]. For Zebu cattle, age at puberty, first oestrus, and first calving were found to be 858, 930, and 1185 days respectively [184, 185]. McDowell (1968) stated that the calving to oestrus was 56 days. McDowell (1972) found that the incidence of anoestrus was only 13% at 80 days postpartum intervals can be attained even in a hot climate.

Progesterone concentrations in the plasma of recently calved cows and delayed puberty heifers were low. According to Sijiu and Beixeng [186], before the first oestrus, plasma progesterone concentrations were 3.9 ± 0.3 nmol/L, and reached 16.6 ± 3.2 nmol/L on day 15 of the cycle. Eduvie et al. [187] stated that a progesterone concentration of 1.59 nmol/L was taken as indicative of attainment of puberty. According to Hansel and Alila [183], the length of the period from parturition to first oestrus varies greatly in cattle in the tropics and is influenced by many factors including, endocrine events, management, nutrition, heat and humidity, genetic-environment interacting, diseases, and external parasites, similarly interval from calving to first oestrus and subsequent pregnancy rare are influenced by prepartum and postpartum nutrition [188–190], sucking status [191, 192].

The major causes of non-infectious infertility in dairy animals are due to energy, protein, and mineral deficiencies mainly of calcium, phosphorus, trace minerals (copper, cobalt, zinc, iodine, and manganese), and other salts [193]. The mean blood zinc levels were higher (p < 0.05) in anestrus than in subestrus and/or repeat breeding cows and buffaloes. Further, the plasma phosphorus, copper, and cobalt concentrations were found to be non-significantly higher in repeat breeders than in anestrus or subestrus cows and buffaloes were deficient in some animals indicating its role in causing infertility in dairy animals.
The plasma levels of phosphorus were found to be non-significantly higher in repeat breeders than in the anestrus or subestrus cattle. Among trace minerals, plasma zinc levels were lower, while copper and cobalt levels were higher in repeat breeder cattle as compared to anestrus or subestrus ones [194]. Kumar et al. [195] and Butani et al. [196].

The mean of studied essential trace minerals in retained placenta (RP) revealed a decline in Zn$^{2+}$, Cu$^{2+}$, and total iron (TF) by 68.9%, 65.7%, and 19.4% respectively. Additionally, all studied minerals exhibited a significant reduction in both non-retained placenta (NRP), and RP groups compared to heifers (HEF) group. Also, it was reported that buffaloes with RP are significantly deficient in Zn$^{2+}$ which has an important role in preserving the uterus following parturition as it helps in the healing process and immune system during the convalescent stage [197]. TF in the case of RP was lower than NRP which attributed to Cu$^{2+}$ reductions as required for the biosynthesis of hemoglobin.

The mineral profile of anestrus cattle results showed that the mean Copper (ppm) for anestrus island cattle was 0.04 ± 0.005 and for coastal cattle was 0.02 ± 0.004. The mean Manganese (ppm) values recorded were 0.031 ± 0.007 in the case of island cattle and 0.024 ± 0.003 for coastal cattle. The mean Zinc (ppm) value in the case of the island and coastal cattle was 0.33 ± 0.11 and 0.33 ± 0.07 respectively. Statistical analysis of the data revealed that there was no significant difference in the values of Copper, Manganese, and Zinc between the cattle of both coastal and island ecosystems.

The mineral profiles of repeat breeder cattle depicted the mean Copper (ppm) for repeat breeder island cattle was 0.05 ± 0.006 and for coastal cattle was 0.03 ± 0.005. The mean Manganese (ppm) values recorded were 0.023 ± 0.005 in the case of island cattle and 0.021 ± 0.004 for coastal cattle. The mean Zinc (ppm) value in the case of the island and coastal cattle was 0.33 ± 0.12 and 0.32 ± 0.09 respectively.

The level of P in cattle of island ecosystem was found to be 3.54 mg/dl, whereas, in coastal ecosystem, the values were 3.60 mg/dl. The present value of P corroborates the finding of Ramakrishna [198].

The serum concentration of zinc (0.32 to 0.33 ppm) was against a normal range of 0.8–1.2 ppm which speaks of a mild deficiency of zinc in the animals. Comparable values have been reported by Sahoo et al. [199]. The serum levels of copper were well within the physiological range (0.7–1.5 ppm) indicating a normal copper level. The observation found the support of Sahoo et al. [199]. The serum manganese during the present study was slightly below the normal range of 0.4–0.8 ppm. A comparable range of manganese levels had been reported by Sahoo et al. [199]. However, lower values had also been reported by Modi et al. [200].

One of the primary constraints limiting livestock production is inadequate nutritional resources on a year-round basis [201]. Many reports reviewed the beneficial effects of mineral supplementation on reproductive performance among animals [143]. Mineral deficiencies in soils and forages have been responsible for low production and reproduction problems among grazing tropical cattle [2]. Molybdenum-induced interference in luteinizing hormone (LH) that delays puberty in heifers is caused by a disruption in ovarian steroid secretion [202].

Zinc importance in spermatogenesis coupled with its synergic role in uptake by spermatozoa of vitamin A, particularly as vitamin A plays an essential role in the attainment of puberty and the maintenance of both libido and integrity of testicular germinate epithelium (Hurley and Doanc, 1989). Master and Moir [203] showed that ewes given a Zn diet (4 mg/kg) produced lambs that were 17% lighter at birth than those receiving an adequate Zn diet (50 mg/kg).

Macpherson et al. [29] showed that the increase in calving rate to the first insemination in dairy heifers is by correcting a selenium deficiency before mating.
Mohammed et al. [204] reviewed that cows with blood selenium concentration > 169 ng/ml had twice the risk of developing cystic ovaries than cows with levels <108 ng/ml. Tasker et al. [205] reported that Se supplementation improves the conception rate. Deficiencies of specific minerals such as Ca, P, Cu, Fe, and I may cause post-partum anoestrus [206] (Surendra Singh and Vadnere, 1987).

The animals showed general weakness, parakeratosis, achromotrichia, and infertility [207]. Suttle [208] reported that the economic importance of Cu deficiencies has been emphasized by the discovery of unsuspected cases of loss, increased susceptibility to cattle. Ingraham et al. [209] illustrated that Cu and Mg supplementation improves the conception rate. Lavin et al. [210] showed that plasma Cu values decreased with advancing gestation, and increased after calving, and were lowest in cows returning repeatedly to service. Dhoble and Gupta [211] discussed the role of Ca and P low values in postpartum anoestrus. Fisher and Macpherson [212] reported that cobalt treatment had a significant effect on ewe serum vitamin B12 and methylmalonic acid concentration. Cobalt deficient ewes produced fewer lambs and had more stillbirth and newborn mortalities than cobalt sufficient controls.

7. Conclusion

Mineral diet can have a significant impact on animal reproduction, as evidenced by the current review. This study would highlight the role of soil minerals in farm animal reproductive function, including infertility, met energy-protein requirements, and mineral deficits. Mineral deficiencies may be a major cause of infertility in dairy cows in different parts of the country. Exotic and crossbreeds showed increased severity of infertility than local breeds. This reflected the increased mineral requirements of these breeds. Compared to milkers, dry cows had severe trace element deficits.

The bulk of the animals with low fertility was found to be weak in P, Cu, Zn, Mn, and Co. Analysis of soils and plants could provide some insight into mineral levels in animal blood. With the use of clinical symptoms and serum analysis, an accurate picture of the animals’ mineral status could be established. Satisfying the animal’s energy-protein requirements is insufficient to express the animal’s maximum reproductive potential. Mineral supplementation in animal diets, particularly those of plant origin, should be addressed.
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