

DOI: 10.18697/ajfand.76.15580**MINERALS AND TRACE ELEMENTS IN THE SOIL-PLANT-ANIMAL
CONTINUUM IN ETHIOPIA: A REVIEW****Girma KB^{1*}****Girma Kibatu Berihie**

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ABSTRACT

Despite Ethiopia's vast agricultural potential and prospects in agriculture-led industrial development, the country faces a set of issues related to minerals and trace elements in its food chain (soil-plant-animal-human). All organisms require a minimum amount of nutrients to maintain good health and productivity. Besides building block elements for macronutrients (water, carbohydrates, fats and proteins) and vitamins, some mineral elements (P, K, Na, Cl, Ca, Mg and S) and trace elements (F, Si, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, and I) are essential for the maintenance of a healthy system. Micronutrient deficiency or excess in any of these elements in the food chain may lead to undesirable conditions that should be prevented or reversed. The aim of this review is to evaluate the status of minerals and trace elements in the country's soil-plant-animal-human continuum based on published and unpublished data. This article provides an overview of the status, causes and effects of common micronutrient deficiencies and options for intervention. Ethiopia faces a wide set of soil fertility challenges including organic matter depletion, macronutrient and micronutrient depletion, top soil erosion, acidity and salinity. The soil system is deficient in total nitrogen, available phosphorous, sulphur, zinc and copper. The absolute amounts of Ca, Mg and K are adequate in the soils; however, the relative proportions indicate K to be high and thus may affect Mg and Ca availability to plants. Even in the presence of adequate amounts of other minerals such as K, Ca, Mg, Fe, B and Mo in the soils, plant uptake is partly dependent on soil type and conditions where uptake can be limited in acidic and saline soils. Livestock productions, which depend on less dense nutrient crop residues, are less likely to supply essential dietary minerals. Besides, vitamin A, calcium, iodine, iron, zinc and selenium deficiencies have been found to be major public health problems. The limitation of access to essential nutrients in the environment and lack of interventions in the soil-plant-animal system can hinder the country from reaching its potential to become a developed and sustainable community. The prevention and control of micronutrient deficiency disorders require a multi-faceted set of policy interventions and research and development activities for locally tailored solutions in areas such as nutrition education, improved methods of food preparation and food diversification, supplementation, mineral fortification, agronomic biofortification (including soil conditioners and specialty fertilizers) and genetic biofortification.

Key words: Minerals, Trace Elements, Calcium, Iodine, Iron, Zinc, Micronutrient Deficiency, Ethiopia



Overview

The quality of life in a given society depends on the chemical composition of the food, the biosphere and physical environment in its surroundings [1]. The natural ecosystem is supposed to be a fundamental system consisting of the community of all living organisms in an environment having a balanced cycle of chemical elements and energy flow. However, the ecosystem has already been considerably modified and such modifications continue. Moving towards sustainability requires understanding and managing the biogeochemical processes that control nutrient cycles and their abundance in ecosystems [2].

All living things require minimum amounts of certain essential elements with known biological roles and functions to maintain optimal health and productivity [3]. There is always an optimal concentration of essential elements required by organisms; above or below the optimal range, in which a toxicity or deficiency state in a system may compromise health, quality and productivity.

Micronutrient deficiencies in humans and animals as well as low agricultural productivity due to unavailability or deficiencies of nutrients, which underline their causes on the biogeochemistry of the environment, are rife in Ethiopia [4]. A better understanding of the biogeochemical processes that control nutrient cycling and abundance in the environment is key to better manage nutrients, which is a prerequisite to sustain land use and, presumably, to diminish health risks due to deficiency or toxicity of micronutrients in the biosphere. This review evaluates the status of minerals and trace elements in Ethiopia's soil-plant-animal-human continuum based on pockets of studies in published and unpublished data in the literature. The review also discusses the causes and effects of common micronutrient deficiencies and the options for intervention to address micronutrient deficiencies in the soil-plant and animal continuum in Ethiopia.

Minerals and trace elements status of the soil

The formation of soil depends primarily on geologic and climatic conditions [5]. The basement upon which younger soil formations in Ethiopia were deposited is the result of a wide variety of sedimentary, volcanic and intrusive Precambrian rock particles, which had metamorphosed through ages to varying degrees mainly by erosion.

The FAO Soil Map of Ethiopia (1998) classifies 19 general clusters of similar soil types that include: *Nitisols* in the southern part of western Ethiopian highlands; *Luvissols* and *Leptosols*, with isolated occurrences of *Cambisols* in the northern part of western Ethiopian highlands; *Luvissols*; *Fluvisols* and *Andosols* in the Rift Valley; and *Vertisols* which are located across the country in small fragments [6]. In general, the potassium and cation exchange capacity (CEC) of most Ethiopian highland soils are generally high by international standards, whereas their available nitrogen, phosphorus and organic content is low to very low and cannot produce high crop yields unless these are supplied by fertilizers [6].

The parent rocks forming the soil contain metallic deposits of Cu, Zn and Pb in many areas associated with fracturing quartz reefs or sulphides. However, essential nutrients



like Cu and Zn might have been eroded away in areas where the soils have been strongly metamorphosed in the south and west highlands of the country while non-essential toxic Pb can be a risk factor for the less metamorphosed soils in the north.

An earlier global project initiated in 1974 by FAO aimed to determine the status of soil micronutrients in agricultural systems in thirty countries showed that wheat cultivar grown on sample soils from Ethiopia presented significant percentages of low concentrations for copper, boron, molybdenum, plus few percentages of low concentrations of iron and zinc showing deficiencies [7].

Recent research works that assessed the status of micronutrients in Ethiopian soils involved soil and plant sample collections from different parts of the country and indicated Zn, B, and Mo are deficient in Vertisols and Nitosols while Cu is deficient in Andisols in the central highlands of Ethiopia [8, 9]. The available Cu and Zn in Luvisols and Cambisols soils in Bale area is low; Fe and Zn fall in deficient range for most Vertisols soil samples in the central highlands while iron, manganese, zinc, and copper contents were low in agricultural fields when compared to natural forest in South East Ethiopia [9-12].

Literature has shown that continuous application of conventional blanket Nitrogen-Phosphorus-Potassium (NPK) fertilizer in farmers' fields without recent data consideration on indigenous soil nutrient supply and managing the adequacy of other essential micronutrients can further limit crop yields [13]. Langu and Dynoodt reported widespread soil acidification, decrease in exchangeable bases (Ca and Mg) and micronutrient deficiencies when high analysis products like Diammonium Phosphate (DAP) and Urea are the only fertilizers continuously used in agricultural systems [13].

The depletion of macro and micronutrients in Ethiopian soils has been recently identified as one of the factors that limit crop yield [6]. Other constraints include: depleted organic matter; top soil erosion; acidity of soils covering over 40% of the country; depletion of soil physical properties, and soil salinity [14]. Furthermore, intensive cropping and use of high yielding varieties and decreased farmyard manure application coupled with synthetic chemical NPK fertilizers only contribute towards accelerated exhaustion of the supply of available micronutrients from the soil bank.

It has been reported that in spite of favourable development in the use of nitrogen and phosphorus fertilizers to increase crop production, two to six times more of the micronutrients are being removed annually through crop harvest from the soil, than are applied [15].

Recent preliminary studies by the Ethiopian Agricultural Transformation Agency (ATA) confirmed that Ethiopia's soil is deficient in as many as six essential nutrients including boron, nitrogen, phosphorus, potassium, sulphur, and zinc. The absolute amounts of Ca, Mg and K are adequate in the soils; however, the relative proportions indicate K to be high and thus may affect Mg and Ca availability. Soil fertility problems related to micronutrient availability depends on several factors such as organic matter content, soil pH, adsorptive surface, soil texture and nutrient interactions in the soil [15]. Even in the



presence of sufficient amounts of minerals such as K, Ca, Mg, Fe, Cu, B and Mo in the soils, plant uptake is partly dependent on soil type and conditions; for example, uptake of Ca, Mg, and Mo can be limited in acidic soils.

Minerals and trace elements status in plants, foods and vegetables

In addition to carbon, hydrogen and oxygen, major macro-elements (N, P, and K), secondary macro-elements (Ca, Mg, and S) and microelements (B, Cl, Cu, Fe, Mn, Mo, and Zn) are essential for the healthy growth of higher plants. If one or more of these elements is deficient, crops will fail to achieve their optimum yields and the quality of their food products is likely to be diminished. In order to provide adequate and quality food for the population, micronutrient deficiencies in agricultural and horticultural crops should be identified and treated wherever they are found [6].

Micronutrient deficiencies in crops occur all over the world including in different areas in Ethiopia [15]. In addition to the decrease in yields, the contents of micronutrients in crop products such as staple grains for humans or livestock foliage for animals are also of great importance to the health of human and livestock consumers, respectively [16]. Nutrient availability to people or livestock is primarily determined by the output of feed produced from agricultural systems.

Many factors such as variety, soil conditions, use of fertilizers, and degree of maturity during harvest and preparation methods affect mineral concentrations of the plants or plant based foods available for consumption.

Small farm holders who largely cultivate 95% of the cropped area and produce predominantly cereals like maize, teff (*Eragrostis teff*), barley, sorghum and wheat followed by pulses and oilseeds for the population dominate the agricultural system in Ethiopia. However, because of the subsistence rain-fed agriculture practices on nutrient depleted soils with little input and poor management, production yields from agriculture are not able to fulfill all nutrient requirements for consumption.

The Ethiopian diet is mainly composed of staple foods from cereals (*teff*, maize, and sorghum), tubers and root crops (*ensete*, potatoes, and sweet potatoes), pulses and oil seeds. Rural communities in the central and northern parts mostly depend on staple cereal crops, and those in the south mostly depend on roots and tuber crops to meet their food needs. Overdependence on a monotonous diet, which contains little amounts of fruits and vegetables and less amounts of animal protein, can lead to a compromised diet in terms of diversity and balanced nutrition [17-19].

The contents and density of minerals and trace elements in some main crops, plant based foods, and drinks from Ethiopia including *teff*, barely, maize, wheat, lentils, gibito, yam, *ensete*, Bulla, Kocho, oleaginous seeds, water, wine, tea coffee and Khat have been determined [20-31]. Plants and plant-based diets studied are rich in essential elements, safe to consume and could be an alternative source of the essential elements for individual daily intake. Ethiopian *teff* (*Eragrostis teff*) is especially dense in many of the essential micronutrients in comparison to other staple crops such as maize, wheat and barley [20]. Ethiopian landrace lentils (*Lens Culinaris Medik.*) accumulate higher zinc



compared to the *teff*, maize, wheat or barley [21]. In general, Kocho and Bulla are rich in Ca and Zn compared to other similar foodstuffs and contains comparable concentrations of Cu, Fe, and Mn [22]. Tea, Coffee, Wine and Khat varieties analyzed contain appropriate concentrations of essential major, minor, and trace metals [23-26].

High proportions of trace elements may enter plant tissue especially from contaminated lithosphere or atmosphere. However, no detectable contents of non-essential Pb, Hg and Cd have been measured in most Ethiopian ecosystems, except where the geochemical elements such as Pb, Zn and As in potable water in Shire area were associated with public health issues related to chronic liver disease [27]. Some potable and bottled waters from ground sources were found to contain appreciable amounts of heavy metals and anions like fluorides, nitrates and phosphates which can change the dissolution of harmful trace elements in the ground and which may not be healthy for babies and people suffering from heart or kidney diseases. Excessive nitrates may originate mainly from current fertilizer practices in the agricultural system causing environmental damage [27, 28].

Tizazu and Emire [29], Getachew [30] and Zelalem and Chandravanshi [31] have studied the chemical composition of lupin seeds grown in Ethiopia. Much as lupin seeds have nutritional benefits, in Ethiopia they can accumulate large amounts of heavy metals from the environment. Levels of minerals in human milk from two populations with cereal and 'Enset' based diets were evaluated [32]. **Tables 1** and **2** show a summary of average means or ranges contents of macro minerals and trace elements in cereal grains, legumes, tuber crops, oil seeds, water and beverages and stimulants from Ethiopia.

Minerals and trace elements status in animals

Reproductive well-being and performance of livestock is determined by four factors: genetic merit, physical environment, nutrition and management [33, 34]. Ethiopia's livestock, the largest in Africa, is contributing little in ensuring food security, mainly attributed to poor feed quality and unavailability of animal feed [35]. Livestock productivity in the country is below the African average. Evidence from the literature suggests that socioeconomic and technical factors including genetic, health and feed quantity and quality directly affect livestock production in the country [33-35].

Livestock well-being and performance in Ethiopia are largely dependent on their nutritional status, which is often less than optimal. Several studies have adequately examined the effects of quantitative feed and energy, as well as qualitative protein and macro-and micronutrients intake on livestock reproductive performance [35-37]. Researchers have examined several crop residues and agro-industrial by-products, available in Ethiopia as potential ruminant feeds in relation to their potential to supply essential dietary minerals [38]. In these studies, it was concluded that in absolute terms, animal diets based on crop residues are unlikely to supply adequate Na, and are marginal to deficient in P, Cu and possibly Zn. Essential nutrients like Mo, I and Se are probably deficient or unavailable. The role and effects of copper, zinc, molybdenum, iodine and selenium on reproductive events and performance in livestock production in Ethiopia are likely to be significant.



The potential effects of essential micronutrients in relatively minute amounts in livestock production have been established [33]. Hence, intensifying research in finding mineral dense foliage resources and production of vitamin–mineral pre-mixes in animal feeds, education and quality control in animal nutrition are important in order to improve the reproductive performance and overall productivity of animals.

Minerals and trace elements status in the populations

The deficiency of essential minerals and trace elements in infants and schoolchildren, women of reproductive age, pregnant and lactating women and the elderly is recognized as a major public health problem in many developing countries. Unavailability or inadequate intakes of dietary micronutrients arising from low intakes and/or poor bioavailability is the major factor in the aetiology of micronutrient deficiencies in developing countries where the vast majority of the population depends on plant-based diets. Trace elements in plant-based foods are less bioavailable for human metabolism due to presence of chelators, phytates and dietary fibre, which inhibit absorption [39].

Children and women are particularly vulnerable to nutritional deficiencies because of the increased metabolic demands imposed by rapid growth and development in children and pregnancy involving a growing placenta, fetus, and maternal tissues, coupled with associated dietary risks. The deficiency of micronutrients in infants and young children may cause compromised growth, failure to thrive and impaired cognitive functions [40, 41].

Several studies on the nutritional micronutrient status in Ethiopia have established that many children and women are affected by micronutrient deficiencies including vitamin A, iodine, iron, zinc, and selenium [40-56]. In a study designed to evaluate the relationship between multiple micronutrient levels and nutritional status among schoolchildren in Gondar town, Northwest Ethiopia, the results showed high prevalence of stunting (23%), underweight (21%), wasting (11%) and intestinal parasites (18%) among the schoolchildren [55]. Selenium deficiency, zinc deficiency and magnesium deficiency occurred in 62%, 47%, and 2% of the schoolchildren, respectively [55]. Deficiencies of selenium and zinc were high among the schoolchildren although the deficiencies were not significantly related with their nutritional status.

In another study by Afewrok Kassu *et al.* [54], serum levels of Zn, Cu, Se, Ca and Mg were determined in 375 pregnant (42 HIV seropositive) and 76 non-pregnant women (20 HIV seropositive) in the University of Gondar Hospital, Gondar, Ethiopia. Irrespective of HIV serostatus, pregnant women had significantly higher serum concentrations of copper and copper/zinc ratio and significantly lower magnesium and zinc compared to those of non-pregnant women ($P < 0.05$). Selenium was significantly lower in HIV-seropositive pregnant women ($P < 0.05$). The magnitude of deficiency in zinc, magnesium, and selenium was significantly higher in HIV seropositive pregnant women (76.2%, 52.4%, and 45.2%, respectively) than in HIV-seronegative pregnant women (65.5%, 22.2%, and 18.9%, respectively) and in HIV-seronegative non-pregnant women (42.9%, 8.1%, and 30.4%, respectively), $P < 0.05$.



Deficiency in one, two, three, or four mineral elements was observed in 44.8%, 14.4%, 9.9%, and 5.1% of the pregnant women, respectively.

Public health conditions associated with micronutrients

Iodine and Iodine Deficiency Disorders

Iodine functions solely as a component of the thyroid hormones [44]. Poor iodine content of soil and water due to environmental iodine deficiency is the main determinant of iodine deficiency disorders in Ethiopia [47, 48]. In 2011, an estimated 12 million school age children were living with inadequate iodine, and 66 million people in Ethiopia were at risk of iodine deficiency [45, 46]. Several studies have been documented on iodine nutrition status in Ethiopia where deficiency and thyrotoxicity has been observed with high prevalence of goitre in communities [47-50].

Iron and Nutritional Iron Deficiency

Iron is an important micronutrient which forms part of haemoglobin, myoglobin and various indispensable enzymes such as cytochrome oxidase in the body. Deficiency may cause anaemia, compromised growth, failure to thrive and impaired cognitive function in young children [41]. The high prevalence of anaemia in infancy is of particular importance in development. This is because the peak velocity in postnatal growth of the brain is in the first year of life hence the damaging effects of its deficiency are long lasting. Studies documented on iron nutrition status in Ethiopia indicate high prevalence of anaemia and iron deficiency disorders in women and children [42, 43].

Zinc and Zinc Deficiency Disorders

Zinc is an essential trace element and constituent of more than 120 metalloenzymes involved in major metabolic pathways in the human body. Zinc deficiency, which is associated with cessation of growth, psychomotor delay, hypogonadism and suppression of both primary and secondary sexual characteristics and intestinal mucosal abnormality, is also prevalent in Ethiopia [51, 52].

Recommended dietary allowances for zinc are: in infants (6 months-1 year), 3-5 mg/day; children (1-10yr), 10 mg/day; adults, 15 mg/day; pregnant women, 20 mg/day; and lactating mothers, 25 mg/day. Zinc supplementation (*Lemelem* plus oral rehydration salt) during diarrhoea has lowered morbidity and mortality in children. Zinc deficient infants showed improvements in growth rate and a reduced incidence of acute lower respiratory tract infection after zinc supplementation. Continuous ingestion of zinc supplements exceeding 15 mg/day is, however, not recommended without adequate medical supervision [51, 52].

Selenium and Selenium Deficiency Disorders

Selenium is a trace element of tremendous importance in human health. Among the essential trace elements in humans, selenium along with zinc, iron and copper are essential for the integrity and optimum function of the immune system [53-55]. Selenium deficiency causes endemic cardiopathy and myocardial infarction. As a constituent of antioxidant defence, several diseases of the neonate have been shown to be caused at least in part by selenium deficiency. High prevalence of selenium deficiency in Ethiopia



was reported in children from Amhara where 58.9% (n=353) had serum Se below 70 µg/l, the cut-off point for deficiency [56]. Selenium deficiency could affect thyroid metabolism of children in Ethiopia, because it is required for biosynthesis of the thyroid hormones. The interactions between Fe, Se and Iodine, and the impact of Fe and Se deficiencies on Iodine status and thyroid metabolism, and their relevance to public health have been reviewed [53]. The major source of selenium for humans is from food. Seafood, kidney, meat and in some countries cereal grains, tend to have high selenium content. Vegetables and fruits are poor sources of selenium. The recommended adult mean dietary selenium intake is 108 µg/day. Excessive intakes have resulted in fingernail changes, hair loss, peripheral neuropathy, and sour milk breath odour [53].

Strategies to combat micronutrient deficiencies

The high prevalence of micronutrient deficiencies in Ethiopia warrants the need for strategies on prevention and control of the deficiencies. Even under the best of circumstances, the current Ethiopian diet cannot fulfill all nutrient requirements and additional interventions are required [40]. Proven and inexpensive technologies and intervention types, such as, *behavioural, fortification, supplementation, regulatory and other health related interventions* exist to address malnutrition and micronutrient deficiency in a population [57]. Strong behavioural changes and practices to diversify diets to include animal-based foods, fruits and vegetables have demonstrated better results in children [58]. Regulatory interventions are those aimed at regulating certain nutrition-related activities or actions, which have an impact on nutrition and health outcomes. Other health-related interventions, such as breastfeeding, deworming and prevention of infections also have an impact on nutrition. A new approach, *biofortification* via agriculture (*agronomic biofortification*) or plant breeding (*genetic engineering* or *genetic biofortification*) has been shown to also be a good strategy [59, 60]. However, their adoption and implementation remains at a low scale in Ethiopia. The country has multifaceted issues with regard to micronutrient deficiencies in its agriculture, food, nutrition health and development, which impose significant costs on the society. To address these, the Ethiopian National Nutrition Program, which translates the strategies of the National Nutrition Strategy (NNS) into actions and the Ethiopian Agricultural Transformation Agency's (ATA) Soil Health and Fertility Program which launched a special initiative to develop Ethiopian Soil Information System (EthioSIS), are expected to play a vital part in micronutrient nutrition and health in soil-plant-animal continuum in Ethiopia. The monitoring and evaluation of these programs is crucial to assess success in the area and plan for future endeavours towards prevention, control and elimination of micronutrient deficiencies.

Conclusion

Essential minerals and trace elements are required by both plants and animals in adequate quantities. In spite of their low requirements, critical biochemical functions that support life are limited if these nutrients are unavailable or deficient. On the other hand, excess intake of these elements may lead to disease and toxicity. Studies on the soil-plant-animal continuum in Ethiopia indicated that the population is highly exposed to deficiencies of some essential minerals and trace elements due to environmental and man-made factors. The prevention and control of micronutrient deficiency disorders require a multi-faceted



set of policy interventions, research and development activities for locally tailored solutions. In view of the importance of essential minerals and trace elements in a sustainable agri-food system, strong commitment by the government and the academia is required to strengthen micronutrient intervention programmes in order to improve the health and nutritional status of the population, which would have a positive impact on economic growth and sustainable development.



Table 1: The minerals and nutrients content in some local crop products sampled from Ethiopia

| Plant and Foods Types | Na | K | Mg | Ca | Phytate | Ref. |
|--|-------------------|------------------|------------------|------------------|---------|------|
| Red <i>teff</i> | 22.06 ± 1.46 | 215.81 ± 8.13 | 161.91 ± 7.76 | 178.54 ± 9.5 | 678 | [20] |
| Mixed <i>teff</i> | 25.68 ± 2.05 | 219.23 ± 8.35 | 173.7 ± 8.89 | 168.64 ± 11.03 | 528 | >> |
| White <i>teff</i> | 22.89 ± 1.42 | 205.59 ± 7.17 | 153.16 ± 9.45 | 180.7 ± 14.65 | 842 | >> |
| Lentil, whole dried | - | - | - | 42 | 561 | [21] |
| Barley, white flour roasted and milled | - | - | - | 40-46 | 370-553 | [17] |
| Maize, whole dried | - | - | - | 16 | 1443 | >> |
| Maize, white flour | - | - | - | 12 | 661 | >> |
| Wheat, whole dried | - | - | - | 41.4 -44.4 | - | >> |
| Yam flour <i>D. abyssinica</i> | 13.3 – 40.5 | 847 -1391 | 18.0 -35.4 | 17.2 -44.8 | - | [22] |
| Koch from <i>Ensete ventricosum</i> | 46.2-68.8 | 275.3-438.0 | 18.0-29.0 | 49.8 -58.4 | - | [22] |
| Bulla from <i>Ensete ventricosum</i> | 40.2 -44.2 | 70.8 -87.5 | 5.84 -8.94 | 38.5 -44.6 | - | [22] |
| Tea Powder mg/100g | - | 1150.3 – 1378.0 | 321.9 – 353.8 | 382.1 – 441.9 | - | [23] |
| Tea infusion mg/100 ml | - | 11.0- 12.4 | 1.45-1.63 | 1.00 – 1.07 | - | >> |
| Coffee powder mg/100g | 48.4±1.2 | 1448.8 ±46.7 | 196.4±7.8 | 94.5±6.5 | - | [24] |
| Coffee infusion mg/100 ml | 0.591±0.02 | 37.205±1.50 | 2.829±0.105 | 1.619±0.102 | - | >> |
| Khat mg/100g | - | - | 44.1-80.2 | 103-203 | - | [25] |
| Bottled water (Tap water) | 18.3-195.4 (2.02) | 2.82-21.9 (1.97) | 1.87-36.3 (1.03) | 5.41-51.4 (9.43) | - | [28] |
| Ethiopian Brand Wines (4) | 24.0-24.4 | 694-767 | 58.1-79.2 | 28.4-37.1 | - | [26] |

Mean ± standard deviation, Range (minimum – maximum); Values are in mg/100gm dry weight or mg/100ml as appropriate



Table 2: The trace elements content in some local crops and food products sampled in Ethiopia

| Plant and Foods Types | Mn | Fe | Co | Cu | Zn | Ref. |
|--|-------------------|-------------------|--------------------|------------------|------------------|------|
| Red <i>teff</i> | 22.36 ± 0.15 | 24.62 ± 1.07 | 6.20 ± 5.38 | 2.51 ± 0.30 | 4.79 ± 10.7 | [20] |
| Mixed <i>teff</i> | 13.26 ± .029 | 20.05 ± 1.4 | 5.21 ± 0.29 | 3.79 ± 0.1 | 3.79 ± 0.1 | >> |
| White <i>teff</i> | 4.84 ± 0.044 | 15.95 ± 1.7 | 7.89 ± 0.75 | 1.08 ± 0.075 | 2.98 ± 0.12 | >> |
| Lentil, whole | 6.7-8.2 | 9.17 – 11.91 | 0.285- 0.360 | 0.226- 0.282 | 8.62 - 10.03 | [21] |
| Barley, white flour roasted and milled | - | 9.4 | - | - | 3.54 | [17] |
| Maize, White, whole dried kernel | - | 4.4 | - | - | 4.04 | >> |
| Maize, white flour | - | 4.9 | - | - | 2.15 | >> |
| Wheat, whole dried | 2.41-4.6 | 1.9-4.1 | - | 0.32-0.62 | 1.81-3.4 | >> |
| Wheat, white flour | - | (1.1)* | - | - | 0.593-0.988 | >> |
| Yam flour <i>D. abyssinica</i> | 1.2-1.45 | 2.8-14.4 | 0.191-0.87 | 0.73-1.8 | 1.2-4.5 | [22] |
| Bulla from <i>Ensete ventricosum</i> | 0.1 – 0.498 | 3.65 -5.98 | 0.50 -0.501 | 0.201-0.353 | 2.2-4.43 | [22] |
| Koch from <i>Ensete ventricosum</i> | 0.858-0.103 | 9.25 -13.5 | 0.55-0.61 | 0.34-0.43 | 3.1-3.21 | [22] |
| Tea Powder mg/100g | 124.2-142.1 | 31.9- 46.7 | <MDL | 0.91-1.15 | 2.02-2.16 | [23] |
| Tea infusion mg/100 ml | 0.85-1.34 | 0.098-0.156 | <MDL | 0.0038- | 0.0098- | [23] |
| Coffee powder mg/100g | 2.3 ±0.09 | 5.2±0.4 | 0.160±0.005 | 1.4± 0.06 | 1.5±0.08 | [24] |
| Coffee infusion mg/100 ml | 0.0237± 0.0012 | 0.0183± 0.0015 | 0.00018± 0.0001 | 0.003± 0.0003 | 0.024± 0.0011 | [24] |
| Khat mg/100g | 0.03-0.600 | 3.72-9.03 | 0.03-0.1 | 0.185-0.553 | 0.518-0.940 | [25] |
| Ethiopian Bottled water (Tap water) | - | 0.079-0.11 | - | 0.08-0.20 | - | [28] |
| Ethiopian Brand Wines (4) | 1.04-1.88 | 1.42-3.16 | ND-0.091 | - | 0.5-1.5 | [26] |

Mean ± standard deviation, Range (minimum – maximum); Values are in mg/100gm dry weight or mg/100ml as appropriate

* Adjusted for digestibility

Table 3: The minerals and trace elements content in local Gibtos (Lupin Seeds) sampled from Ethiopia

| Lupin | Mg | Ca | Mn | Fe | Zn | Pb | Reference |
|-----------|----------|------------|----------|-----------|-----------|-----------|-----------|
| Ethiopia | 173.9- | 50.2- 96.7 | 165.7- | 7.79-9.28 | 4.03-5.36 | 1.08-1.64 | [29, 31] |
| Debretabo | 203.9±7. | 97.98±1.7 | 165.7±6. | 8.52±0.06 | 5.36±0.0 | 1.36±0.0 | [29, 31] |
| Dembecha | 173.9±5. | 67.13±1.2 | 409.5±8. | 16.49±0.4 | 4.03±0.0 | 1.08±0.0 | [29, 31] |
| Kossober | 215.9± 6 | 76.4±1.0 | 317.5±7. | 8.7±0.17 | 4.46±0.0 | 1.64±0.0 | [29, 31] |

Mean ± standard deviation. Values are in mg/100gm dry weight



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