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Mineral Contents of Selected Medicinal and Stimulating Plants in Ethiopia

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Abstract

Mineral elements play a critical role in building body tissues and regulating numerous physiological processes. They are thus essential constituents of enzymes and hormones; regulate a variety of physiological processes, and are required for the growth and maintenance of tissues and bones. Living organisms (including plants, animals and microorganisms) store and transport metals so as to get appropriate concentration for later uses in physiological reactions as well as a means of protection against the toxic effects of the metals. This paper reviews the mineral contents of medicinal and stimulating plants in Ethiopia.

Medicinal Plants

Thyme

Thyme is cultivated in almost every country, as an aromatic for culinary uses. The two species, *Thymus schimperi* Ronniger and *Thymus serrulatus* Hochst. ex Benth are endemic to the Ethiopian highlands growing on edges of roads, in open grassland, on bare rocks and on slopes, between 2,200-4,000 m altitudes. Both species are perennial herbs, woody at the base and 5-40 cm high. The volatile oil from thyme was found to contain p-cymene, γ-terpine, carvacrol, rosmarinic acid, eugenol, and thymol [1]. The volatile oil not only has carminative action, but also antiseptic, antimicrobial and antifungal activities [2]. In the Ethiopian traditional medicine the plant has many medicinal applications. Some of the reported applications are for the treatment of gonorrhea, cough, inflammation, spasm, thrombosis, urinary retention, mental illness, eye disease, toothache, stomach problems, leprosy, lung TB, acne, and ascaris [3].

The fresh or dried leaves of both species are used locally as condiments in the preparation of chili powder, stew, bread and tea. The contents of some selected metals Ca, Mg, Fe, Mn, Co, Cu, Zn, Ni, and Cd in different thyme leaf samples widely consumed in Ethiopia were determined by flame atomic absorption spectrometry. The level of the minerals in the four samples ranged from 1,239-2,517, Ca; 1,524-1,786, Mg; 728-2,517, Fe; 37.7-114, Mn; 2.59-4.3, Co; 7.69-9.3, Cu; 8.7-52, Zn; and 9.83-14.2 µg/g, Ni; respectively. While the level of toxic metal Cd in the four samples ranged from 0.87-1.3 µg/g. The concentration of Ca was higher than the other metals in the three samples and Cd was the least of all the metals in the analyzed samples [4].

Gesho

(*Rhamnus prinoides*) (Amharic, Gesho) is a wide spread plant species in Ethiopia and other east and south African countries. *R. prinoides* has been used for bitterness in the traditional brewing process in East Africa. *R. prinoides* has potential use as a commercial hopping agent in the beer industry. An extract of leaves and stems of this plant (a naphthalene glycoside, Geshoidin) is responsible for bitterness in local alcoholic beverages [5]. In Ethiopia, the leaves and stems of this plant are used to impart the characteristic bitter flavor to domestically brewed beverages such as (*Tella, Tej*) [6]. *R. prinoides* has also several traditional medicinal uses in Africa. A decoction of the root is taken as a blood purifier, to treat pneumonia, gonorrhea, rheumatism, stomach-ache, flu/cold, back pain, brucellosis, strength/nutrient supplement, and enhancing digestion [7]. The boiled soup of the root is used for the treatment of common cold, leaves are used for chest pain and leaves/stems are used for the treatment of tonsil in central Kenya [7].

Extract of *R. prinoides* is used for the inhibition of Alzheimer's disease. Extract of the leaf and root bark of *R. prinoides* has been also used for malaria treatment either alone or in combination with chloroquine in Kenya. The levels of essential metals (Ca, Mg, Cr, Mn, Fe, Co, Ni, Cu and Zn) and toxic metals (Cd and Pb) in the leaves and stems of *Rhamnus prinoides* (Gesho) cultivated in Ethiopia were determined by flame atomic absorption spectrometry. The

levels (mg/kg) of the metals were found to be: Ca (6304-22236), Mg (3202-5706), Cr (5.08-20.6), Mn (8.12-17.9), Fe (47.9-187), Co (22.2-42.1), Ni (12.8-27.3), Cu (6.5-73.0), Zn (12.2-43), Cd (0.81-3.10), and Pb (17.7-25.0) in the leaf samples and Ca (3601-5675), Mg (2635-5528), Cr (ND-16.3), Mn (2.16-3.98), Fe (22.0-124), Co (18.7-91.7), Ni (9.68-19.2), Cu (16.8-233), Zn (17.4-28.2), and Cd (ND-1.56) in the stem samples. The study showed that the leaf and stem of *R. prinoides* (Gesho) are good sources of essential minerals and virtually free from toxic metal Cd but not from Pb in the leaf [8].

Linseed

Linseed *Linum usitatissimum* stands fourth after mustard, sesame and groundnut in edible oil production of the world. Linseed has been a traditional crop in Ethiopia. Ethiopia is the 5th major producer of linseed in the world after Canada, China, United States and India [9]. Linseed is a multi-purpose crop. Its' seeds containing about 36-40% of oil, have long been used in human and animal diets and in industry as a source of oil and as a basic component or additive of various paints or polymers. Recently, there has been a growing interest in the probiotic properties of flax and in its beneficial effects on coronary heart disease, some kinds of cancer and neurological and hormonal disorders [10]. The beneficial effects are mostly due to flax lipids. Flax oil is the richest plant source of linoleic (omega-6) and linolenic (omega-3) polyunsaturated fatty acids, which are essential for humans since they cannot be synthesized in the organism and must be ingested in food [11].

Scientific research over the past decade all over the world is indicating health benefits of omega-3 type oils, lignin and other soluble fiber present in the flax seed/linseed. Some of the medicinal uses of linseed oil are: flax seed oil mixed with an equal quantity of limewater, is an excellent applicant for burns and scolds, rectal injection has been recommended for piles, freshly extracted oil is used as a laxative, linseed oil is a vehicle for irritant drugs, linseed tea is used as a demulcent in cough especially those forms due to irritation of pharynx and upper part of respiratory passage. It is also used as a demulcent drink in intestinal or urinary catarrhs), for the preparation of cough syrup mucilage of linseed is used, crushed linseed is used in the form of poultice to apply warmth and moisture locally for the relief of superficial or deep rooted inflammation. The poultice may be sprinkled with boric acid previous to application.

The poultice mass is enclosed in muslin, the surface of poultice may be smeared with oil to keep it adhering to skin), linseed/flax seed and its oil have anti-inflammatory action the treatment of arthritis, feeding linseed and its oil may be indicated in hyperlipidemia to decrease platelet aggregation and also to reduce and control atherosclerosis, thrombosis and myocardial infarction by reducing cholesterol and low density lipids. The levels of essential and non-essential metals in linseed samples collected from five different sites (Bale, East Gojam, Shoa, South Wello and Tigray) in Ethiopia were determined by flame atomic absorption spectrometry. The levels (mg kg^{-1}) of metals determined were in the ranges Na (242-614), K (6,494-6,755), Mg (2,679-3,118), Ca (540-744), Cr (13-30), Mn (17-28), Fe (198-242), Co (23-42), Ni (12-16), Cu (25-45), Zn (29-40), and Pb (12-32). Cd was not detected. K and Fe were with the highest concentration from major and trace metals, respectively. The study indicated that Ethiopian linseed is a good source of essential metals and free from the toxic metal Cd but not from Pb [12].

Croton

Ethiopia has a long history of traditional medicine and has developed ways to combat disease through it. In Ethiopia up to 80% of the population uses traditional medicine due to the cultural acceptability of healers and local pharmacopeias, the relatively low cost of traditional medicine and difficult access to modern health facilities [13]. Of the many medicinal plants in Ethiopia, *Croton macrostachyus* is the most common. *Croton macrostachyus* Hochst. ex Del. is commonly known as rush foil or broad-leaved Croton. It is native to Eritrea, Ethiopia, Kenya, Tanzania, Uganda and Nigeria. As *C. macrostachyus* is available almost in all parts of Ethiopia, people are using it as a medicine for treatment of snakebite, malaria, headache, internal worms, rabies, gonorrhea, ascarasis, sexually transmitted diseases and tinea versicolor for human being in which the traditional medician ordered the patients to take unlimited dosage of the plants part like to take two, three or even more glasses of medicinal plant extract orally.

The plant is also used for fever and wounds of domestic animals [14]. The leaves of *Croton macrostachyus* have medicinal value including cold leaf decoction is drunk or ashes taken orally as treatment for cough; juice from fresh leaves is applied on wounds to hasten clotting. The levels of essential metals (Ca, Mg, Fe, Mn, Zn, Cu, Co, Cr, Ni) and toxic metals (Cd, Pb) were determined in the leaves of *Croton macrostachyus* (traditional medicinal plant) collected from four different regions of Ethiopia (Akaki, Abomsa, Bonga and Dilla) and also in the infusions of leaves collected from Akaki using flame atomic absorption spectrometry. The mean concentration ranges (µg/g) were Ca (5,823-12,040), Mg (1,971-4,961), Fe (192-581), Mn (157-1,770), Zn (19.5-60.5), Cu (6.31-18.6), Co (1.97-3.45), Cr (2.13-8.75), Ni (2.15-3.80), Cd (0.75-1.08) and Pb (1.05-2.19) in the leave powders and Ca (716-1,776), Mg (16.7-80.9), Fe (1.39-3.34), Mn (2.17-3.40), Zn (0.674-7.88), Cu (1.94-2.31), Co (0.157-0.224), Cr (0.144-1.23), Ni (0.203-0.267), Cd (0.05-0.098) and Pb (0.0148-0.185) in the infusion samples. Among the quantified metals in the infusion samples, Ca showed the highest leaching rate (61.5%) in the 24 h infusion while Fe exhibit the lowest (1%) leaching rate in the 3 h infusion [15].

Fenugreek

Trigonella foenum-graecum (fenugreek) is native to Ethiopia and to the area from the Eastern Mediterranean to Central Asia, and is widely cultivated in Pakistan, India and China [16]. Fenugreek seeds contain about 50% fiber and also contain protein, saponins and the hypoglycemic phytochemicals coumarin, fenugreekine, nicotinic acid, phytic acid, scopoletin and trigonelline and 4-hydroxyisoleucine. Fenugreek seeds have high contents of iron, calcium, zinc, lysins and β-carotene and are a rich source of flavonoid compounds such as quercetin, luteolin, kaempferol, tricin and gallic acid [17]. Fenugreek leaves and seeds are consumed in

different countries around the world for different purposes, such as medicinal uses (anti-diabetic, lowering the blood sugar and cholesterol levels, anti-cancer, anti-microbial, against breast cancer, avoiding blood poisoning from wounds, making food (stew with rice in Iran, flavoring cheese in Switzerland, syrup and bitter rum in Germany, mixed seed powder with flour for making flat bread in Egypt, curries, dyes, young seedlings for eating as a vegetable), roasted grain as a coffee-substitute (in Africa), controlling insects in grain storages and perfume industries.

The seeds of this ancient herb have been used as both a spice and a herbal remedy in the Middle East, India, and Egypt and later on in Europe, China and other parts of the world [18]. Fenugreek seeds have been reported for their pharmaceutical properties in treating such human diseases as diabetes and hypercholesterolemia [18]. In Ethiopia fenugreek is cultivated between altitudes of 1600 and 2300 m above sea level all over the country and is used in preparing "Hilbet", a delicious, traditional, soft white food in the Tigray regional state. It is also used to make tea, "Enjera", flat bread mostly made of "tef" flour, as a spice in milk and in traditional medicine. The levels of the major (Ca, K, Na, Mg), trace (Fe, Cr, Ni, Zn, Mn, Cu, Co), and toxic (Pb, Cd) metals in the seeds of fenugreek cultivated in different regions of Ethiopia were determined by flame atomic absorption spectrophotometry. Thirteen elements were determined, obtaining concentrations (mg kg^{-1}) in the following ranges: Ca (15353-36771) > Fe (6041-18584) ≈ K (6789-11517) > Pb (615-2624) > Na (201-1559) > Cd (285-464) > Cr (3-552) > Ni (31-108) > Mg (31-102) > Zn (15-33) > Mn (16-28) > Cu (ND-35) > Co (4-15). The study showed that fenugreek seeds were a good source of essential metals. However, they also contained large amounts of the toxic metals Cd and Pb and therefore should not be consumed daily [19].

Stimulating Plants

Khat

Khat (*Catha edulis* Forsk) is an evergreen shrub or tree found growing wild or cultivated in the east of a region extending from Southern Africa to the Arabian Peninsula more specifically in Yemen, Ethiopia, Kenya, Madagascar, Somalia, Tanzania, and others as well. The most favored part of the plant is its leaves, particularly the young shoots near the top of the plant. However, leaves and stems at the middle and lower sections are also used. Khat is chewed for its stimulating property. This is due to the presence of the phenylalkylamines in the plant [20]. There is an ever-growing demand of khat in Ethiopia both for domestic consumption and for the export market. Most of the exported khat is grown in the eastern part of the country and mainly exported to the neighboring and the Middle East countries, and in recent years, the market for khat has grown to Europe and America [21].

Report indicates that over 20 million people in the Arabian Peninsula and East Africa chewed this plant daily [20]. Khat use is widespread and cultivated in most parts of Ethiopia, where its use is socially sanctioned and even prestigious [22]. In Ethiopia, the plant is marked under different names: Awadai, Kuto, Gelemso, Gurage, Wendo, Sebeta, Bahir Dar, Liyu, Chengie, Berdaye, Anferara, Colombia, etc. Of these, only some of them are commonly available in the capital city, Addis Ababa, and exported to the neighboring countries while the remaining is chewed by the local people around. The levels of essential (Ca, Mg, Mn, Fe, Zn, Cr, Cu, and Co) and non-essential (Cd and Pb) metal in six different varieties of Ethiopian khat chewing leaves were determined by flame atomic absorption spectrometry. The concentrations ranges in fresh-weight basis were recorded in decreasing order: Ca (1,038-2,173 μg/g) > Mg (478.2-812.3 μg/g) > Fe (53.95-82.83 μg/g) > Zn (5.18-9.40 μg/g) > Mn (6.98-8.66 μg/g) > Cu (1.85-5.53 μg/g) > Cr (0.66-3.47 μg/g) > Co (0.41-0.80 μg/g). A wide variation in the mineral contents of khat from different region of Ethiopia was noticed. The toxic metals (Pb and Cd) were not detected in all the samples analyzed [23].

Cannabis

Cannabis (*Cannabis sativa* L.) is an annual herbaceous plant. It is a dioecious plant. In many countries, cannabis is cultivated as a narcotic substance or a source of narcotic substances like hashish and hashish oil. Now a day's cannabis is cultivated on the large areas with the mild and tropical climate for the cannabis oil and fiber [24]. The highest levels of cannabis production in the world take place in the African continent. The crude drug can be obtained from leaves, flowers, seeds and stem of cannabis. It can be smoked in cigarettes or pipes and can be snuffed or added to food [25]. Cannabis products are the most widely trafficked drugs worldwide. Practically all countries in the world are affected by cannabis trafficking [24].

A small amount of cannabis is produced in rural areas of Ethiopia, of which a small portion is exported, primarily to the neighboring countries; the majority is consumed at home, but absolute quantities in both cases are moderate. The chemical composition of cannabis varies with the type, age and part (flower, root, leaf, fiber, etc.) of cannabis plant as well as with the type of preparation. While Δ9-tetrahydrocannabinol is responsible for psychoactive properties of cannabis some of the other components modulate its activity. *Cannabis sativa* L. is known for millennia for its therapeutic properties and as a recreational psychoactive drug [26]. The levels of selected metals in leaves of *Cannabis sativa* L. cultivated in four different regions of Ethiopia were determined by flame atomic absorption spectrometry. The levels of metals determined (μg/g dry weight) were in the ranges Ca (657-1,511), Zn (321-380), Ni (124-172), Cu (122-176), Cd (3-10), Pb (8-10), and Cr (4-8). Zn was with the highest concentration among trace metals [27]. The results indicated that the content of Pb and Cd exceeded the permissible amount for medicinal plants which form the raw materials for the finished products set by World Health Organization (WHO) [27].

Tobacco

Tobacco (*Nicotiana tabacum* L.) is a commercial plant. Tobacco is one of the basic agricultural products, in Ethiopia, with social and economic importance. Native tobacco ('gaya') has been used for snuffing, chewing and for pipe smoking in many places. Three main types of commercial tobacco are produced in Ethiopia: Virginia, Oriental and Burley. Virginia accounts for a little more than 74%

of the total production, followed by Oriental, 22%, and Burley, 4% [28]. United Nations Office on Drugs and Crime report [29] reveals that in Ethiopia peoples commonly use khat, tobacco, and alcohol, which have a share of 48.2, 29.9 and 18.9%, respectively, of all type of drugs. This clearly shows that tobacco made significant contribution as a drug in Ethiopia. Tobacco leaves are used for cigarette production and chewing. It naturally accumulates and concentrates relatively high levels of heavy metals and particular cadmium in leaves [30].

Cadmium is a non-essential to both plant and human. It is highly toxic and gets accumulated by tobacco plants. Most heavy metals cause a significantly serious damage on human health [31]. One of the main sources of toxic metals in our environment is tobacco smoke. Cigarette smoking is a major source of intake of these toxic elements not only to the smoker but also, through passive smoking, to nonsmokers. The distribution and accumulation of metals in tobacco leaves are the reflection of the mineral composition of the soil and environment in which the tobacco plant grows. Therefore, the actual metals content of tobacco vary considerably according geographic origin, the use of fertilizers with different chemical compositions and other characterizing features such as water for irrigation [32].

The levels of heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) were determined in the raw and processed Ethiopian Virginia tobacco leaves collected from two different regions (Billate and Shewa Robit) of Ethiopia and three processed tobacco samples collected from National Tobacco Enterprise, Addis Ababa, Ethiopia by flame atomic absorption spectrometry. The mean metals concentrations (in µg/g dry weight) in the raw Virginia tobacco leaves from Billate and Shewa Robit, respectively, were: Cu (4.38, 7.30), Zn (53.7, 33.2), Cd (1.20, 1.30), Cr (ND, 1.45), Ni (ND, 1.90). The mean metals concentrations (in µg/g dry weight) in the processed tobacco from Billate and Shewa Robit, respectively, were: Cu (9.80, 12.8), Ni (2.35, 2.20) Cd (1.45, 1.90), Cr (1.65, 1.75), Zn (101, 83.8). The mean metals concentrations (in µg/g dry weight) in the processed tobacco Nyala (Ethiopian cigarette leaves) were: Cu (8.95), Cd (1.55), Cr (1.62), Ni (4.70), Zn (79.3). The study showed that the metal contents of tobacco leaves varied with the geographical origin in which the tobacco plant grows. The metal contents of processed tobacco were higher than the corresponding raw leaves. Pb was not detected in both the raw and processed Ethiopian tobacco leaves [33].

Conclusion

The level of metals in Ethiopian thyme is a comparable result with other medicinal plants. The concentration of Fe in thyme is higher than the values reported by different authors in other medicinal plants. The concentration of potentially toxic metal (Cd) in thyme ranges from 0.87-1.3 µg/g. This concentration is above the WHO acceptable level (maximum 0.3 mg/kg). The leaf and stem of (*R. prinoides*) (Gesho), which are used in the preparation of traditional alcoholic beverages in Ethiopia, are good sources of essential minerals and virtually free from toxic metals. The levels of metals in *R. prinoides* are in good agreement with the most of reported values for all the studied metals except Mn and Fe which are lower in the leaves of *R. prinoides* than in the leaves of most other medicinal plants.

Ethiopian linseed accumulates relatively higher amounts of K and Pb among the essential and nonessential metals, respectively. The non-essential heavy metal, Cd, was not detected. The contents of minerals in Ethiopian linseed are within the daily recommended level and thus advisable as healthy food for treatment of different health complications. *C. macrostachyus* (an Ethiopian traditional medicinal plant) accumulated appreciable amounts of major and traces metals in its leaves. Ca and Mg were the most abundant nutrients followed by, Fe, Mn and Zn. All the metals enriched in the extract proportionally with extraction time but extent of leaching in the extract was significantly pronounced for the trace metals and the toxic metals (Cd and Pb) for prolonged period of infusion. Thus, beside its medicinal value, *C. macrostachyus* leaves can be good source of mineral nutrients.

Ethiopian fenugreek seeds are a good source of essential metals. However, they also contained large amounts of the toxic metals Cd and Pb and therefore should not be consumed daily. Prolonged accumulation of heavy metals ingested via foodstuffs may lead to chronic effects on the kidney and liver of humans and cause the disruption of numerous biochemical processes, leading to cardiovascular, nervous, and kidney and bone diseases.

Ethiopian khat varieties contains appropriate concentration of essential major, minor, and trace metals, and they could be source of dietary minerals and trace metals. The toxic heavy metals (Cd and Pb) were found to be too low to be detected by the available technique (FAAS) indicating that the widely chewable and commercially available Ethiopian khat are free from environmental pollution due to non-essential heavy metals. Ethiopian *Cannabis sativa* L contains higher levels of essential metals Ca, Zn and Cu. But highly toxic metals like Pb and Cd were also detected in *Cannabis sativa* L The content of both toxic metals are beyond permitted limits set by WHO. This will further lead to the harmful effect of *Cannabis sativa* L. on human health. In general, the levels of metals in the Ethiopian cannabis are comparable to those reported in the literature from other countries.

The heavy metal component of Ethiopian tobacco is comparable with that of other countries' tobacco. Pb was not detected in the Ethiopian tobacco leaves which make the Ethiopian tobacco free this toxic heavy metal. Cd concentration in Ethiopian tobacco was found to be comparable with industrialized countries and greater than that naturally available in the soil. The study also revealed that there is large difference between the heavy metal content of raw tobacco leaves and processed tobacco. This indicates that the metal contents that determined in cigarette are not only the content of raw tobacco leaves itself but also the metal originated from contamination of raw tobacco leaves during the process, starting from harvesting to cigarette manufacturing. The study also revealed the dependence of metal accumulation in tobacco leaves on the geographical origin in which tobacco plant grows.

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