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Review

Review of the antioxidant properties of wild edible plants in Ethiopia

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This work aims to study the potential and importance of wild edible plants (WEPs) as antioxidants in treating different diseases caused by free radicals. A total of 67 species belonging to 50 genera under 36 families and naturally growing in Ethiopia were recorded after assessing all available documents. About 16.2% of the total (413) WEPs were recorded in the country. The plant families with more number of species known to have antioxidants are Amaranthaceae and Moraceae 7 species each. Fruits are the dominant edible parts followed by leaves. Compounds such as tannins, oxalates and phenolic acids are the major contributors to the antioxidant activity of vegetables, fruits and medicinal plants. Plants also have many phytochemicals which are a potential source of natural antioxidants such as phenolic diterpenes, flavonoids, flavonols, alkaloids, iridoids and saponins, High consumption of fruits and vegetables is associated with a lowered occurrence of cancer, heart disease, inflammation, arthritis, neurodegenerative diseases and diabetes. Antioxidant components including vitamin C, vitamin E, carotenoid, and plant polyphenols appeared to play a key role in reducing the development of such diseases. This review gives a general overview of the antioxidant properties of different parts of WEPs in a single volume and ease selection of the best species for further research. The chemical composition, antioxidant contents and energy values of wild plants consumed by Ethiopians indicated that they provide key nutrients such as carbohydrates minerals and vitamins. The plants will be lost along with their valuable nutrients and indigenous knowledge without proper management and conservation in the right places and habitats.

Keywords: antioxidant, Ethiopia, health benefit, phytochemicals, wild edible plants.

INTRODUCTION

It is indicated that wild plants used as leafy vegetables and fruits have recently attracted attention as sources of natural antioxidants. Many of these wild-collected vegetables and fruits contain antioxidants such as vitamins (β-carotene, vitamins C and E) and polyphenols (flavonoids, tannins, catechins) (Wong et al., 2006).

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Epidemiological studies have shown that a diet rich in vegetables and fruits can reduce the incidence of cardiovascular diseases, inflammation, arthritis, immune related diseases and certain cancers (Block et al., 1992; Krishan et al., 2014).

Plants used in foods like fruits, vegetables and whole grains contain many components beneficial to human health. Research supports that some of these foods, as part of an overall healthful diet, have the potential to delay the onset of many age-related diseases and these have further led to continued research aimed at identifying dietary bioactive components including antioxidants, which may be responsible for improving and maintaining health (Knight, 2000).

Plants which have high amounts of vitamins or carotenoids also have high antioxidant activities (Chanwitheesuk et al., 2005). Many compounds (for example, vitamins C and E, carotenoids, chlorophyll derivatives, alkaloids, flavonoids, phenolic acids, and other phenol) of higher plants are associated with antioxidants properties. Plant extracts also contain other types of antioxidants derived from secondary metabolites including volatile oils and carotenoids.

Antioxidants are compounds that result in the neutralization of free radicals and simultaneous oxidation inhibition of other vital molecules (Sies, 1996). They undergo oxidation terminating the chain by reacting with free radicals and chelating catalytic metals. Free radicals are mainly derived from oxygen (reactive oxygen species, ROS) and nitrogen (reactive nitrogen species, RNS) and generated in the human body by various endogenous systems, exposure to different physicochemical conditions (such as exposure to ultraviolet light and toxic chemicals), inflammatory or pathophysiological states (He and Hader, 2002). Free radicals contribute to the reduction of risks associated with cardiovascular and degenerative diseases through the reduction of oxidative stress and counteraction of macromolecular oxidation.

The ethnobotanical profile of wild plants consumed in Ethiopia and their antioxidant activities, phytochemical constituents, method of standardization and dietary intake needs reviewing. The main objective of this review was to document and provide information on the potential wild edible plants as antioxidants to the local communities of Ethiopia. In addition, this work suggests to document the available information on the antioxidant properties of wild edible plants in the country to pinpoint existing gaps in research. Thus, this review bridges the information gaps regarding the antioxidant potentials of wild edible plants. Taking into account these facts, antioxidant activities of wild edible plants and their ethnobotanical information were reviewed to show their antioxidant potentials.

The paper shall make available information scattered in different sources to inform the public, herbalists, natural product researchers and other users. In this paper, we present the review of information found in published journals, databases, books, proceedings, and other relevant documents. In short, the data on antioxidant properties of Ethiopian wild edible plants were systematically gathered and compiled after assessing accessible documents. Analysis was made by using descriptive statistics to generate graphs, tables, charts, central tendencies, and percentages.

REVIEW AND ANALYSIS ON WILD EDIBLE PLANTS AS SOURCES OF ANTIOXIDANTS

Overview of antioxidant plants

Studies have shown that phenolic compounds were having linkages with antioxidant activity of the plants. Thus, improved health and nutrition can be achieved not only by the consumption of fruits and vegetables having high antioxidant capacities but also from the medicinal herbs (Atawodi, 2005). According to Amoo et al. (2012), medicinal plants are sources of antioxidant compounds that can be used in food preparation and pharmaceutical formulations. Fruits are a significant part of the human diet, providing fiber, minerals, vitamins, and other beneficial compounds such as antioxidants. Edible berries are a potential source of natural anthocyanin antioxidants and have shown a broad spectrum of biomedical functions (Charles, 2013).

Sources of natural antioxidants and their activities

Large numbers of plant sources including many vegetables and fruits have been explored for their antioxidant potential (Krishna et al*.,* 2014). There are several sources of natural antioxidants, such as herbs and spices. Moreover, there are other natural products such as cereals, nuts, oilseeds, legumes, vegetables, animal products and microbial products which can serve as rich sources of natural antioxidants (Charles, 2013). The richest sources of polyphenols are various spices and dried herbs, cocoa products, some darkly colored berries, some seeds (flaxseed) and nuts (chestnut, hazelnut), and some vegetables, including olive and globe artichoke heads with contents varying from 15,000 mg/100 g in cloves to 10 mg/100 mL in rose wine. The same author further explains that banana, custard apple, orange, lemon, guava, and papaya were found to be very rich in ascorbic acid. Among vegetables, capsicum (green sweet pepper), cauliflower, bitter gourd, round gourd, beetroot, spinach, cabbage, and radish contained high concentrations of ascorbic acid. Plants, including herbs and spices have many phytochemicals which are a potential source of natural antioxidant, e.g., phenolic diterpenes, flavonoids, alkaloids, tannins and phenolic acids. Natural antioxidants are known to protect cells from damage induced by oxidative stress, which is generally considered as being a cause of aging, degenerative diseases, and cancer (Kim et al., 2011).

Reports noted that medicinal plants are an important source of antioxidants. Natural antioxidants increase the antioxidant capacity of the plasma and reduce the risk of certain diseases such as cancer, heart diseases, and stroke. The secondary metabolites like phenolics and flavonoids have been reported to be potent free radical scavengers. These secondary metabolites are found in all parts of plants such as leaves, fruits, seeds, roots and bark (Mathew and Abraham, 2006). On the other hand, there are many synthetic antioxidants in use. It is reported, however, that antioxidants have several side effects, such as a risk of liver damage, and carcinogenesis in laboratory animals (Gao et al., 2001). There is, therefore, a need for more effective, less toxic and cost-effective antioxidants.

Secondary metabolites

Mankind has been exploiting plant chemicals in the form of potions and poisons for thousands of years. The attitude toward the physiological significance of this plethora of small molecules is reflected in the terminology that was assigned to them, namely secondary metabolites (Kutchan, 2001). Secondary metabolites may be referred to as chemical substances that are not directly involved in the growth and development of plants. Such metabolites are known to participate in plant defense mechanisms (against herbivores, pathogens and allelopathy) by their repellent or attractive properties, protection against biotic and abiotic stresses-which include adaptation to changing environments and the maintenance of structural integrity (Achakzai et al., 2009). The most common classes of these chemicals are saponins, tannins, anthraquinones, flavonoids and alkaloids, which are widely distributed amongst various plant families in abundant quantities. That is why these secondary metabolites attract so much attention from biological scientists because of their ability to inhibit the growth of microbes pathogenic to humans (Pereira et al., 2009).

A breakthrough in the study of the enzymology of secondary metabolite formation came with the establishment of plant cell suspension cultures that produce quantities of secondary metabolites that match or surpass those levels found in plants (Heller and Forkmann, 1994). With the discovery of physiological roles for secondary metabolites such as jasmonates, brassinosteroids, and flavonols in critical processes in plant growth and development, Kutchan (2001) further explains that secondary metabolites have an integral role in plant growth, development, symbiosis, and reproduction. They are no longer only fortuitously formed chemicals that serve mankind as pharmaceuticals and pesticides. In conclusion, secondary metabolites can provide a local or a systemic defense response to pathogen and herbivore attack.

Dietary intake of polyphenols and antioxidants

It was postulated that estimated daily flavonoid and phenolic intake at approximately one gram per day, with flavonols (catechins and proanthocyanidins) account for the largest share (Scalbert et al., 2002). It was also elaborated that the daily intake of phenolic substances may be as high as 1 g per day, but the quantity of defined flavonoids in the diet probably amounts to not more than a few tens of milligrams per day.

The same study further elaborates that foods and beverages contribute roughly equally to total phenolic intake, with phenolic acids accounting for about one-third and flavonoids for two-thirds, although the coffee and/or tea consumption by an individual significantly affects the relative contribution from foods and beverages. It was also reported that consumption can vary greatly across the population. A study of Dutch dietary intake of quercetin showed more than a 10-fold difference in average daily intake between the 10th and 90th percentile cohorts. Consumption in the United States, Denmark, and Holland has been estimated at 20 to 25 mg per day (Manach et al*.,* 2004). Phenolic acid intake in Germany was found to vary from 6 to 987 mg/day.

Antioxidant activities of wild edible plants

The degenerative diseases associated with aging include cancer, cardiovascular disease, immune-system decline, brain dysfunction, and cataracts. They are also associated with free radicals because of oxidative damage to DNA, proteins and other macromolecules accumulate with age and have been postulated to be the major type of endogenous damage leading to aging (Fraga et al., 1990).

Humans evolved on a diet that was balanced in the omega-6 and omega-3 polyunsaturated fatty acids and was high in antioxidants (Simopoulos, 2004). The author also explained that wild edible plants provide alpha-linolenic acid and higher amounts of vitamin E and vitamin C than cultivated plants. In addition, wild edible plants are rich in phenols and other compounds that increase their antioxidant capacity. Natural antioxidants from plant sources are potent and safe due to their harmless nature; many wild herbs have been investigated for their antioxidant properties (Lee et al., 2004).

On one hand, fruits are considered to be rich in antioxidants but the total antioxidant potential is yet to be unveiled systematically in case of wild edible fruits (Patnaik and Basak, 2014). However, the consumption of fruits with a high antioxidant composition has been associated with a lowered incidence of chronic, degenerative diseases (Cox et al., 2000) including cancer, coronary heart disease, inflammation, arthritis, immune system decline, brain dysfunction, cataracts, attitude sickness (Kumpulainen and Salonen, 1999), digestive, stomachic complications, various biological activities like lipid-lowering effect (Vijaya et al., 2009). On the other hand, wild green leafy vegetables increase the amount of blood in the body which is likely to refer to the high iron content of many wild greens (Misra et al., 2004).

Antioxidants are present in foods as vitamins, minerals, carotenoids, and polyphenols, among others. Many antioxidants are often identified in food by their distinctive colors the deep red of cherries and of tomatoes; the orange of carrots; the yellow of corn, mangos, and saffron; and the blue-purple of blueberries, blackberries, and grapes (Halliwell and Gutteridge, 2003). The authors also indicated that the most well-known components of food with antioxidant activities are vitamins A, C, and E; -carotene; the mineral selenium; and more recently, the compound lycopene. It has been proposed that the antioxidant properties of phenolic compounds can be mediated by the following mechanisms: (1) scavenging radical species such as ROS/RNS; (2) suppressing ROS/RNS formation by inhibiting some enzymes or chelating trace metals involved in free radical production; (3) up-regulating or protecting antioxidant defense (Bors and Michel, 2002). It was reported that higher intake of oxalate is known to cause renal disorder by forming kidney stones in humans (Addis et al., 2013). Therefore, excess intake of green leafy vegetables that are rich in oxalates should be limited to promote better absorption of minerals and prevent internal health problems. These authors explained that green leafy vegetables of wild and semi-wild origin generally contain higher levels of nutrients and anti-nutritional factors comparable to cultivated green vegetables.

Wild edible plants as sources of food and/or nutrition in Ethiopia

Wild edible plants (WEPs), with nutritional and medicinal benefits, are frequently underutilized as local solutions to food insecurity and associated health concerns (Kaschula, 2008). Wild plants contributed higher amounts of vitamin E and vitamin C, and other antioxidants than cultivated plants, providing additional protection against cancer, and atherosclerosis. Because of the importance of wild plant food sources, it would be beneficial to understand how these plants contribute to human health and nutrition, and to recognize their potential for sustaining populations during future food shortages (Hegazy et al., 2013). Even though wild food plants represent a minor contribution to family meals, they are potentially important nutrient and cultural resources for local people around the world. They often contain higher amount of nutrients and bioactive compounds than many cultivated species, especially those which have been under cultivation for many generations (Martins et al*.,* 2011).

The research clearly shows that human beings evolved on a diet that was based on wild plants, particularly green leafy vegetables, meat from animals in the wild, and fish from rivers, lakes and deep cold seawater. This diet provided equal amounts of omega-6 and omega-3 essential fatty acids (Simopoulos, 2004). The same author noted that studies on wild plants relative to the omega-3 fatty acids and antioxidant content are being carried out in various parts of the world. As expected, they showed enormous variation in the content of both omega-3 fatty acids and antioxidants due to variation in climatic conditions and cultivars.

The review has shown that 413 wild edibles belonging to 224 genera and 77 families in Ethiopia and indicated their potential to combat food insecurity (Lulekal et al., 2011). Earlier sources, though scattered, presented the same number of species. The actual number of wild edible plants in Ethiopia is expected to be more than the presently cited number given a large flora of more than 6000 species, many cultures and localities that remain ethnobotanically unexplored yet. The proportion of wild vegetables is known to be high and the degree of consumption varies from one socio-cultural setting to the other. On the other hand, in addition to the conventional crops, the Ethiopian flora contains many wild plants that produce quantities of food. Hence, the natural vegetation of the wilderness, farmlands and home gardens are sources of edible plants (Wondimu et al., 2006).

Studies indicated that the rural populations of Ethiopia have a wider knowledge, tradition and opportunity of using WEPs despite the variation in age, sex, time and season (Getachew et al., 2013). Because of this reason, they are an essential part of the diet of many rural communities and so have diverse contributions in various ways. The use of wild plants has been reported by different authors (Hunde et al., 2011; Bahru et al*.,* 2013). Wild edible plants have been used in Ethiopia during the time of food scarcity. The ethnobotanical studies conducted in Ethiopia address the role played by various plant species (Balemie and Kibebew, 2006). Research has shown that hundreds of edibles including many vegetables of wild/semi-wild origin are known to be sporadically consumed by rural communities in Ethiopia (Addis et al., 2013). The authors further explained WEPs are important sources of essential vitamins and minerals, carbohydrates, proteins, lipids and fiber for the rural communities.

Contribution of wild edible plants as food medicines

Many herbal medicinal plants are consumed as food. There is no clear dividing line between food and medicinal plants in both indigenous and local traditions. Food can be used as medicine and vice versa. Certain WEPs are still used because of their assumed health benefits, thus they can be classified as medicinal foods; among these plants are *Allium erdelli* which consumed because it is perceived to protect from high blood pressure (Etkin, 1994). In this review paper, 67 WEPs were recorded and all of them have been cited as food and medicinal plants (Table 1).

Studies indicated that there has been growing interest in functional foods, that is, foods that can provide not only basic nutritional and energetic requirements but also an additional physiological benefit. Fruits are considered to be major sources of dietary antioxidant compounds. Fruits possess self-defense mechanism for protection from oxidative stress by the activation of many antioxidant defense enzymes (Jacob, 1995). The consumption of fruits with a high antioxidant composition has been associated with a lowered incidence of chronic, degenerative diseases (Cox et al., 2000) including cancer, coronary heart disease, inflammation, arthritis, immune system decline, brain dysfunction, cataracts, attitude sickness, digestive, stomachic complications, various biological activities like lipid-lowering effect (Kumpulainen and Salonen, 1999; Vijaya et al., 2009).

Marketed wild edible plants and their roles as sources of antioxidants

It was pointed out that WEPs are important to household food security and dietary diversification in some rural areas, particularly in the drylands, to supplement the staple food, to fill the gap of seasonal food shortages and as emergency food during famine, prolonged drought or social unrest (Asfaw and Tadesse, 2001; Balemie and Kibebew, 2006; Wondimu et al., 2006; Assefa and Abebe, 2011; Addis et al., 2013; Bahru et al*.,* 2013).

Based on various literatures survey, 67 Ethiopian WEPs were recorded as food, medicines and have antioxidant values (Table 1). This shows that about 16.2% of the WEPs growing in Ethiopia have antioxidant values. This also accounts for 1.1% of the total number of plants in the country. It was also indicated that some of the recorded species are marketable and provide the opportunity to supplement household income (Balemie and Kibebew, 2006). It was also reported that in addition to household consumption, various WEPs are sold at local markets, roadsides and villages to supplement household income (Bahru et al., 2013). Income derived from the sale of wild edible plant species is of particular importance to people having low incomes in order to meet their basic needs (Assefa and Abebe, 2011; Hunde et al., 2011). According to Balemie and Kibebew (2006), *Moringa stenopetala* and *Solanum macrocarpon* are commonly marketed in the study area. The same authors indicated that some wild edibles such as *Balanites aegyptiaca, Opuntia ficus-indica, Leptadenia hastate* and *Ximenia americana* are also occasionally marketed at Gato market place by children and some Kusume women. Other economically important and marketable species is *Cordia africana*. It is the most preferred timber species and fetches high prices at the local market.

Similarly, other researchers signified that fruits of *Mimusops kummel* and *Ziziphus mucronata* are sold in the local market (Wondimu et al., 2006). *Tamarindus indica* was reported as one of the wild edible plants to have good local market demand (Asfaw and Tadesse, 2001). The marketability of WEPs in the study area was very low due to small production and supply (Hunde et al., 2011). In general, it must be noted that income derived from the sale of wild plant species is of particular importance to the poorer households who must supplement food production with cash in order to meet basic needs.

Description of some antioxidant compounds of wild edible plants in Ethiopia

Studies were undertaken related to wild edible plants as potential antioxidants by different researchers. Of the total recorded WEPs having antioxidant properties and nutritional values of plants growing in Ethiopia, Addis et al*.* (2013) reported the nutritional profile of *Urtica simensis* and also reported 15 semi-wild and wild edible plants of total mineral composition as well as their phenolics, tannis and oxalates contents; Fekadu (2014) on anti-nutritional factors of *Coccinia abyssinica*; Tewolde-Berhan et al*.* (2013) indicated the antioxidant power and total phenols in *Cordia africana* fruit, and Tadesse et al. (2007) revealed antioxidant activity of three *Rubus* spp. Mekonnen and Dräger (2003) reported on the glucosinolates contents in seeds, leaves and roots of *Moring stenopetala*. Another study by Ayele et al. (2013) reported the polyphenol content and cytotoxicity of methanol extracts of various parts of eight food plants from Ethiopia.

The above plant species and the remaining ones which are commonly grown in Ethiopia were also reported by a number of researchers outside Ethiopia (Table 1). In Burkina Faso, 11 plants were reported by Lamien-Meda et al. (2008) and Ibrahim et al. (2011); five from South Africa (Abdillahi et al., 2011; Amoo et al., 2012; Zhen et al., 2015); three from India (Patnaik and Basak, 2014; Vijaya et al., 2009); three from Nigeria (Bello et al., 2011; Adediwura and Bola, 2013); four (two each) from America (Zhen et al., 2015) and China (Ju et al., 2003); Middle

Table 1. List of wild edible plants of Ethiopia containing antioxidants that combat free radicals and diseases**.**

Scientific names	Family	English and commonly used vernacular name	Parts studied	Uses and chemical constituents	Sources
Acacia nilotica (L.) Willd. ex Del.	Fabaceae	*Gum Arabic tree*	branches, leaves, fruits*)*	Free radical scavenging potentialities	Moustafa et al. (2014)
Adansonia digitata L.	Bobacaceae	Baobab*; Ethiopian* sour gourd	*Fruit, leaf*	Strong antioxidant, high phenolic and flavonoid, high natural vitamin C, content, anti-inflammatory properties, anti trypanosoma activity, anti-diarrhea activity. Treat many diseases	Lamien-Meda et al. (2008); Chadare et al. (2009); Ayele et al. (2013)
Adenia ellenbekii Harms	Passifloraceae	Kaguto (Konso)	Leaves	Tannins, oxalates, phenolics, micronutrients, amino acids and so on	Addis et al*.* (2013)
Amaranthus caudatus L.	Amaranthaceae	Velvet flower	Leaves, grain	Contains tocotrienol and tocopherol decrease of cholesterol level, potent antioxidant activity. Having nutrients	Danz and Lupton (1992); Andrea and Plate (2002)
Amaranthus dubius Thell.	Amaranthaceae	Red spinach	Leaves	Higher levels of phytochemicals and also exhibited more potent antioxidant (highest flavonoid and phenolic content)	Ibrahim et al. (2011); Moyo et al*.* (2013)
Amaranthus graecizans L.	Amaranthaceae	Amaranth	Leaves	Potent antioxidant activity, tannins, oxalates, phenolics, micronutrients	Ibrahim et al. (2011)
Amaranthus hybridus L	Amaranthaceae	Amaranth pigweed	Leaves	polyphenols, flavonoids, flavonols and proteins. Potent antioxidant activity, bioactive compounds and have nutrients	Ofukoya et al. (2007)
Amaranthus viridis L.	Amaranthaceae	Slender Amaranth	Leaves	Of polyphenols, flavonoids, flavonols and proteins contents.	Ibrahim et al. (2011)
Amorphophallus gomboczianus Pichi-Serm.	Araceae	Pakanna (Konso)	Tubers	Highest level of carbohydrate, least phenolics and tannins. Minerals present.	Addis et al. (2013)
Annona senegalensis Pers.	Annonaceae	Wild sour sop	Leaf, root-bark	Diarrhea, stomach pain, and abscesses; antioxidant activity and drug detoxification activity	Cordeiro (2012)
Argemone mexicana L.	Papaveraceae	Mexican poppy	Leaf	The plant has the potential to be used as a medicine against the diseases caused by free radicals, alkaloids	Sharma et al. (2013)
Balanites aegyptiaca (L.) Del.	Balanitaceae	Desert date	Fruit/ leaves	Phenolics, tannins and oxalic acid	Addis et al. (2013); Hegazy et al. (2013)
Bidens pilosa L.	Asteraceae	Black jack	Leaf and stem	Antiradical activity	Muchuweti et al. *(*2007)
Carissa spinarum L	Apocynaceae	Conker berry	Root	Free radical scavenging properties.	Hegde and Joshi (2010)
Celtis africana Burm. f.	Ulmaceae	White stinkwood	leaves and stems	Phenolics; treatment of cancer, indigestion and edema	Adedapo et al. (2009)
Citrullus lanatus (Thunb.) Matsum & Nakai	Cucurbitaceae	Watermelon	Fruit	Citrulline, lycopene and citrulline, beta carotene; powerful antioxidant	Schaefer and Renner (2011)
Clausena anisata (Willd.) Benth.	Rutaceae	Horse wood	Leaves	Phenolic and flavonoids	Amoo et al. (2012); Cordeiro (2012)
Celosia argentea L.	Amaranthaceae	Cock's comb.	Leaves	High oxalates, tannins high nutritional value, treat diseases such as jaundic phenolics, steroids,	Addis et al. (2013); Nidavani et al. (2013)

Table 1. Contd.

				diterpenes, and flavonoids, gonorrhea, wounds, fever, inflammation, itching, mouth sores, and diarrhea	
Cleome gynandra L.	Capparidaceae	Spider plant	Leaves and flower buds	Spider plant is nutritious. It is known to contain high levels of beta-carotene, vitamin C, and moderate levels of calcium, magnesium, and iron. The plant contains high crude protein, lipids, and phenolic compounds (highest phenolic content).	Muchuweti et al. (2007); Cordeiro (2012)
Coccinia abyssinica (Lam.) Cogn.	Cucurbitaceae	Anchote (Amharic)	Tuber	Phytate, tannin, oxalate and cyanide	Fekadu (2014)
Coccinia grandis (L.) Voigt	Cucurbitaceae	Ivy gourd	Leaves	Antihyperglycemia, high protein contents, Phenolics, tannins and oxalic acid	Chanwitheesuk et al. (2005)
Corchorus aestuans L.	Tiliaceae	Jute	Leaves	Presence of flavonoids, carbohydrates, saponins, phytosterols, phenolic compounds, triterpenoids, cardiac glycosides and tannins; antioxidants	Patel and Patel (2013)
Corchorus trilocularis L.	Tiliaceae	Awachuwaey (Anuak,)	Leaves	Phenolics, tannins and oxalic acid; minerals, amino acids	Addis et al. (2013)
Cordia africana Lam.	Boraginaceae	Cordia	Fruit	Fruit with good quantities of total phenol antioxidants	Tewolde-Berhan et al. (2013)
Cordia sinensis Lam	Boraginaceae	Cordia	Aerial parts	Anti-glycation properties of the plant phenolics	Al-Musayeib et al. (2011)
Cucumis dipsaceus Ehrenb ex. Spach	Cucurbitaceae	Teasel gourd, hedgehog,	Leaves, fruits	Antioxidant and nutritional properties	Nivedhini et al. (2014)
Cyperus esculentus L.	Cyperaceae	Tiger nuts	Tuber	Hepatoprotective and antioxidant activities, cancer, some inflammatory disorders	Soltan et al. (2002)
Cyperus rotundus L.	Cyperaceae	Nut grass	Tuber	hepatoprotective and antioxidant some inflammatory disorders, cancer, antidiabetic activity *in vivo* and *in vitro*	Soltan et al. (2002)
Datura stramonium L.	Solanaceae	Datura	Leaves	Secondary metabolites such as alkaloids, flavonoids, terpenes,tannins, saponins, iridoids, glycosides and sterols are present	Sreenivasa et al. (2012)
Digera muricata (L.) Mart.	Amaranthaceae	False amaranth	Stem, leaf, root	Laxative; diabetic rich source of phenols, tannins, terpenoids, flavonoids and glycosides	Jagatha and Senthilkumar (2011); Mety et al. (2011)
Diospyros mespiliformis Hochst. ex A.	Ebenaceae	jackal-berry	Fruit	Phenolic and flavonoids	Lamien-Meda et al. (2008)
Dioscorea bulbifera L.	Dioscoreaceae	"air potato", aerial yam	Tuber, bulbs	High value nutritive and natural store of antioxidant, treatment of sore throat, gastri-cancer and carcinoma of the rectum	Gao et al. (2001)
Ekebergia capensis (Sparrm.)	Meliaceae	Dog plum	Leaves and Twigs	Iridoid, phenolic and flavonoid contents	Amoo et al. (2012); Cordeiro (2012)
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	Loquat	Fruit	Caffeic-acid cyanidin kaempferol Quercetin, oleanolic-acid rutin ursolic-acid, fruits shows very high amount of antioxidant property and is a potential source of natural antioxidant	Ju et al. (2003)

Table 1. Contd.

Ficus palmata Forssk.	Moraceae	Wild fig	Fruit, leaf	Presence of alkaloids, tannins, flavonoids, terpenoids and cardiac glycosides; anti-carcinogenic activity	Chauhan et al. (2012); Joshi et al. (2014)
Ficus thonningii Blume	Moraceae	Fig	Leaves	Antioxidants activities. Comprise flavonoid, tannin and alkaloid	Yusuf and Muritala (2013)
F*icus platyphylla* Del.	Moraceae	Flake-rubber	Fruit	Possess analgesic anti-inflammatory and anticonceptive activities	Ramde-Tiendrebeogo et al. (2012)
Ficus sur Forssk.	Moraceae	Fig tree, bush fig	Fruit	Phenolic (tannins and flavonoids)	Ramde-Tiendrebeogo et al. (2012); Ayele et al., (2013)
Ficus sychomorous L.	Moraceae	Fig tree	Flesh with peel and seed	Phytochemical constituents including alkaloids, carbohydrates, flavonoids, saponins, steroids, tannins, phenols, triterpenoids, anthracenosides, anthocyanins and coumarin	Lamien-Meda et al. (2008); Ramde-Tiendrebeogo et al. (2012)
Justicia flava (Vahl) Vahl	Acanthaceae	Yellow justicia	Leaves	Comparable amounts of the minerals and possess oxalate, phenolics and tannins.	Addis et al. (2013)
Justicia ladanoides Lam.	Acanthaceae	Justicia	Leaves	Comparable amounts of the minerals, high calcium level and possess oxalate, phenolics and tannins.	Addis et al. (2013)
Lantana camara L.	Verbenaceae	Lantana	Leaves	Have lantadenes, these are the pentacyclic triterpenoids. alkaloids, essential oils, phenolics compounds, flavonoids, iridoid glycosides, phenyl ethanoid, quinine, saponins, steroids, triterpens, sesquiterpenoides and tannin	Mahdi (2012); Kalita et al. (2013)
Launaea intybacea (Jacq.) Beauverd	Asteraceae	Hankolayita (Konso)	Leaves	Minerals, tannins, oxalates and phenolics	Addis et al. (2013)
Leptadenia hastata (Pers.) Decne.	Asclepiadaceae	Cheila (Konso)	Leaves	Polyphenolic content and alpha-glucosidase inhibitory potential; annins, flavonoids, proanthocyanidins, alkaloids and saponins.	Bello et al. (2011); Addis et al. (2013)
Mimusops kummel Bruce ex A.DC.	Sapotaceae	Monesia-Bark	Pulp	Polyphenol and tannic acid	Ayele et al. (2013)
Moringa stenopetala (Bak. f.) Cufod.	Moringaceae	Bottle tree	Leaves, seeds	High nutrients, antioxidants and glucosinolates, and low oxalate contents; used to treat disease caused by visceral leishmaniasis or kala-azar	Mekonnen and Dräger, (2003); Yang et al. (2006); Ayele et al. (2013)
Morus alba L.	Moraceae	White mulberry	Fruit	Strong antioxidant	Nikolova et al. (2011)
Morus mesozygia Stapf	Moraceae	African mulberry	Stem bark	Flavonoids, antidepressant	Kapche et al. (2009); Adediwura and Bola (2013)
Ocimum americanum L.	Lamiaceae	Hairy/sweet basil	Leaves, shoot	Carminative, relieve cold; terpene hydrocarbons; very powerful hydroxyl radical scavenging activity	Chanwitheesuk et al. (200); Sishu et al. (2010)
Olea europaea L. *subsp. cuspidata* (Wall. ex G. Don) Cif.	Oleaceae	Olive	Leaves	potential of triterpenoids isolated from the leaves of olive	Amoo et al. (2012)
Pachycymbium laticoronum (M.G. Gilbert) M.G. Gilbert	Asclepiadaceae	---------------	Aerial Succulent	Phenolics, tannins and oxalic acid and having micronutrients	Addis et al. (2013)

Table 1. Contd.

Pentarrhinum insipidum E. Mey.	Asclepiadaceae	African heart-vine	Leaves	Phenolics, tannins and oxalic acid	Addis et al. (2013)
Podocarpus falcatus falcatus (Thunb.) R. Br. ex Mirb.	Podocarpaceae	Quteniqua yellowwood	Leaf, stem	Exhibited significant anti-inflammatory, Antioxidant and antityrosinase.	Abdillahi et al. (2011)
P*ortulaca oleracea* L.	Portulacaceae	Purslane	Leaves	Antioxidants and phenolic compounds. Chlorogenic, caffeic, *p*-coumaric, ferulic and rosmarinic acids were the free phenolic acids, and quercetin and kaempferol were the free flavonoids.	Aberoumand and Deokule, (2009); Naciye (2012)
Prosopis juliflora (Sw.) DC.	Fabaceae	mesquite tree	Leaves	Antibacterial and antioxidant properties, Important source of flavonoids	Prasad et al. (2011); Ayele et al. (2013)
Rubus apetalus Poir.	Rosaceae	Raspberry	Leaves	Antidiabetic agents, free radical scavenging activity	Tadesse et al. (2007)
Rubus steudneri Schweinf.	Rosaceae	Blackberry	Leaves	Antioxidant, anti-diabetic agents used for the treatment of diabetes mellitus.	Tadesse et al., (2007)
Solanum nigrum L	Solanaceae	black nightshade; African nightshade	Leaves	The presence of alkaloids, reducing sugars, gallic acid, flavonoids, phlobatannis, steroids, tannis, catechin, protocatechuic acid, caffeic acid, epicatechin; to treat various ailments such as inflammation, pain, fever and enteric diseases; natural antioxidant to inhibit lipid per oxidation in foods.	Chauhan et al. (2012); Cordeiro (2012); Padmashree et al. (2014)
Schinus molle L.	Anacardiaceae	False pepper	Leaves and fruits	Monoterpene hydrocarbons, namely α-phellandrene, β-phellandrene, β-myrcene, limonene and α-pinene. Used as antibacterial, antiviral, topical antiseptic, antifungal, antioxidant, anti-inflammatory, anti-tumoural as well as antispasmodic and analgesic effect.	Martins et al. (2014)
Tamarindus indica L.	Fabaceae	Tamarind tree	Fruit, seeds and pericap	The fruit is rich in phenolic components such as epicatechin, catechin and oligomeric proanthcyanidins may be an important source of cancer chemopreventive natural products	Lamien-Meda et al. (2008)
Ximenia americana L.	Olacaceae	Sea lemon	Fruit	Highest phenolic and flavonoid contents	Lamien-Meda et al. (2008); Zhen et al. (2015)
Ximenia caffra Sond.	Olacaceae	large sour plum	Leaf, fruit	Leaf exhibits antioxidant property and tannis and phenolics are present, having antiproliferation, and anti-inflammatory activities	Addis et al., (2013); Zhen et al. (2015)
Vitellaria paradoxa Gaertn. f.	Sapotaceae	Shea butter tree	Fruit	Phenolic and flavonoids	Lamien-Meda et al. (2008)
Urtica simensis Steudel	Urticaceae	Nettle	Leaves	Polyphenol and tannic acid	Addis et al. (2013); Ayele et al. (2013)
Vitex doniana Sweet	Verbenaceae	Black plum	Fruit	Has antioxidant properties and used for the treatment of jaundice and liver.	Ajiboye (2015)

Table 1. ContD.

Ziziphus mauritiana Lam.	Rhamnaceae	Indian Plum	Fruits	Possess phenolic and flavonoid and used to treat ulcers, fevers, nausea, vomiting, liver trouble, asthma, fever, cough, wound, skin disease, ulcers, stomatitis, sexual weakness and so on.	Lamien-Meda et al. (2008); Cordeiro (2012); Patnaik and Basak (2014)
Ziziphus mucronata Willd.	Rhamnaceae	Buffalo thorn	Leaf	Iridoid, phenolic and flavonoid	Amoo et al. (2012)

East (Hegazy et al., 2013); Tanzania (Cordeiro, 2012) and so on account of one or more species from each country (Table 1).

Adansonia digitata

Since time immemorial, many plants (such *A. digitata*) have been used to inhibit inflammation-related diseases, since they contain thousands of phytochemicals (Manach et al., 2004). Baobab fruit pulp, which is traditionally used to treat many diseases, has also been recognized as a botanical remedy due to its antioxidant effect (Chadare et al., 2009).

Another study found that *A. digitata* leaves, fruit-pulp and seeds have earlier been reported to show antiviral activity against influenza virus, herpes simplex virus and respiratory syncytial virus and polio (Anani et al., 2000). Chemical analyses have reported the presence of various potentially bioactive ingredients including triterpenoids, flavonoids and phenolic compounds (Chadare et al., 2009). These bioactive compounds, especially flavonoids and phenolics, may be responsible for the nutritive and medicinal properties of this vegetable.

Several studies have also reported that the species has strong antioxidant, possesses a high natural vitamin C content, anti-inflammatory properties, anti-trypanosomal activity and anti-diarrhea activity (Lamien-Meda et al., 2008; Ayele et al., 2013).

Amaranthus species

Amaranthus plants (Amaranthaceae) are spread throughout the world, growing under a wide range of climatic conditions and they are known to infest or to produce useful feed and food products. The leaves of amaranthus constitute an inexpensive and rich source of protein, carotenoids, vitamin C and dietary fiber, minerals like calcium, iron, zinc, magnesium and phosphorus (Shukla et al., 2006). The amaranthus species namely *Amaranthus dubius, A. graecizans*, *A. hybridus* and *A. viridis* are rich in microelements (Na, K, Ca, Mg, P, Fe, Mn, Zn, and Cu), flavonoids, flavonols, proteins, carotenoids and other potent compounds. The oxalate amount in these species is fairly high. The highest mineral contents and the antioxidant activity of amaranthus could explain their large use by all the socioeconomic strata of the population (Table 1) (Ofukoya et al., 2007; Ibrahim et al., 2011; Addis et al., 2013). In the amaranthus species, appreciably present the same chemical profile but with different amounts (Ibrahim et al., 2011). The same authors postulated that *A. hybridus* and *A. dubius* content have high level of mineral and proteins. The amounts of protein and micro elements explain their uses especially in infantile nutrition as a food supplement. They also reported that everyday consumption of the above amaranthus could have a positive impact on pathologies like cancers, diabetes, and hypertension and neurodegenerative diseases.

Furthermore, WEPs such as *Celosia argentea* under the family Amaranthaceae is widely used in traditional medicine to cure many diseases such as jaundice, gonorrhea, wounds, fever, inflammation, itching, mouth sores, and diarrhea. A variety of phyto-constituents are isolated from the *C. argentea* which includes novel triterpenoid saponins, a known compound cristatain, betalains, nicotinic acid, anti-inflammatory, immune-stimulating, anticancer, hepatoprotective, antioxidant (Nidavani et al., 2013) (Table 1).

Several studies have reported that the seeds and leaves, although with similar levels of total phenolics and antioxidant activity, had a different level of carotenoids. It can thus be concluded that the antioxidant activity of mainly due to phenolics, while in the leaves, the carotenoids may play a major role in antioxidant activity. In some cases, the two components may act together.

Ficus species

The phytochemical screening of the *Ficus palmata* plant extracts showed the presence of alkaloids, tannins,flavonoids, terpenoids and cardiac glycosides (Chauhan et al., 2012). The whole fruit, along with the seeds, is edible. Fruit is raw and very tasty. It is sweet and juicy, having some astringency, which is due to the presence of white latex just beneath the epicarp (Joshi et al*.,* 2014).

Results have shown that *Ficus platyphylla* possesses analgesic anti-inflammatory and anti-conceptive activities. Phytochemical constituents of *F. sycomorous* include alkaloids, carbohydrates, flavonoids, saponins, steroids, tannins, phenols, triterpenoids, anthracenosides, anthocyanins, and coumarin (Table 1) (Lamien-Meda et al., 2008; Ramde-Tiendrebeogo et al., 2012). On the other hand, it was reported that the concentrations of phenolic compounds, tannins and flavonoids were higher in *F. sycomorus* extract when compared with the *F. sur* extract (Ramde-Tiendrebeogo et al., 2012; Ayele et al., 2013). *F. thonningii* includes compounds such as flavonoids, tannins, alkaloids and antioxidants mg/100 g (Yusuf and Muritala, 2013).

Morus **species**

Investigations on plants of the Moraceae family have been of great interest due to its numerous biological compounds (Kuete et al., 2009). The phytochemical profile showed that members of the genus *Morus* are rich in alkaloids, flavonoids, and polyphenols (Song et al., 2009). Previous studies revealed antimicrobial activity of the methanol crude extract and isolated compounds from *M. mesozygia*, (Kuete et al., 2009) as well as isolation of prenylated arylbenzofuranes with antioxidant activity (Kapche et al., 2009). Similarly, it was also shown that *M. alba* has strong antioxidant properties (Nikolova et al., 2011).

Urtica simensis

The Fe and Zn content of *U. simensis* (SAMMA in Amharic) were found to be high compared to other similar vegetables found in Ethiopia and elsewhere (Getachew et al., 2013). The respective amounts of Fe and Zn in Lagos Spinach (*Celosia argentea*), Lenghui (*U. dioica*) and Spinach (*Amaranthus virids*) were 28.3 and 0.2 mg, 8.9 and 0.15 mg, 8.8 and 0.25 mg per 100 gm, respectively. The range of Fe content of the tested samples is comparable with Bitter Letuce (*Launae cornuta*) (44.60 mg/100 gm) and African spider flower (*Gynandropsis gynandra*) (47.01 mg/100gm) (Noor et al., 2008). Thus, green leafy wild *Samma* contains a high concentration of both macro-and micronutrients. Hence, *Samma*, if it is included in the daily diet of a person, will have a significant contribution to the recommended daily allowance of a person (Addis et al., 2013). The same authors demonstrated that the anti-nutritional content of raw *Samma* leaves from Ethiopia containing tannin ranged from 25.3-27.0 mg/100 g while oxalate was 8.59-9.33 mg/100 g. It was found that *Samma* has a high nutritional value compared to many green leafy vegetables commonly cultivated and consumed in Ethiopia. Its protein and mineral content is exceptionally high which makes this vegetable an inexpensive but high-quality nutrition source especially for the poor segment of the population where malnutrition is prevalent (Addis et al., 2013).

Ascorbic acid content of raw *Samma* leaves was also higher compared to cultivated green leafy vegetables consumed in Ethiopia spinach (*Spinacea oleracea*) (32 g/100 g), lettuce (*Lactuca sativa*) (6 g/100 g) and Swiss chard (*Beta vulgaris*) (18 g/100 g) and Kale (*Brassica carinata*) (2 mg/100 g) (EHNRI, 1997).

In general, in Ethiopia, other plant species such as *Annona senegalensis, Cyperus esculentus, Cyperus rotundus, Corchorus aestuans, Datura stramonium, Digera muricata, Diospyros mespiliformis, Ekebergia capensis, Justicia flava, J. ladanoides, Mimusops kummel, Moringa stenopetala, Ocimum americanum, Rubus apetalus, R. steudneri, Solanum nigrum, Ximenia caffra, Vitellaria paradoxa*, *Ximenia Americana* and *Ziziphus mauritiana* have different valuable compounds including the antioxidants (Table 1). Their fruits and other parts are traditionally consumed as a food source as well as for medicinal purposes (Lulekal et al., 2011) (Table 1). Fruits with high antioxidant activities were found to possess high phenolic and flavonoid contents. It is also indicated that there was a strong correlation between total phenolic and flavonoid levels and antioxidant activities (Lamien-Meda et al., 2008).

Taxonomic diversity of Ethiopian plants with antioxidant properties

Habit diversity of antioxidant wild edible plants

This review paper documents 67 wild edible plant species with antioxidant properties distributed across 50 genera and 36 families that are naturally growing in Ethiopia (Tables 1 and 2). In addition, the review shows that the most widely used WEPs habit with antioxidant properties in the different study areas of Ethiopia and elsewhere in the world were trees with 27 (40%) species followed by herbs 26 (39%). Shrubs and climbers account for 8 (12%) and 6 (9%) respectively (Figure 1; Tables 1 and 2). Herbs are the dominant habits among the reported WEPs; this may be because the plant species exhibit a high level of diversity, are easy to access and/or randomly selected by researchers. Such diversity is well known in the different regions of the country. This is because of the combined effects of topographic and climatic factors; the country is

Table 2. Wild edible plants known to have antioxidants along with their habit and parts used.

S/N	Scientific Names	Habit	Parts used	S/N	Scientific Names	Habit	Parts Used
1	*Acacia nilotica*	Tree	Bark & fruit	17	*Clausena anisata*	Shrub	Fruit
2	*Adansonia digitata*	Tree	Fruit	18	*Celosia argentea*	Herb	Leaf
3	*Adenia ellenbekii*	Herb	Leaf	19	*Cleome gynandra*	Herb	Young shoot
4	*Amaranthus caudatus*	Herb	Leaf	20	*Coccinia abyssinica*	Climber	Shoots, tubers, fruits
5	*Amaranthus dubius*	Herb	Young shoot	21	*Coccinia grandis*	Climber	Fruit
6	*Amaranthus graecizans*	Herb	Young leaf	22	*Corchorus aestuans*	Herb	Leaf
7	*Amaranthus hybridus*	Herb	Seed	23	*Corchorus trilocularis*	Herb	Young leaf
8	*Amaranthus viridis*	Herb	Young shoot	24	*Cordia africana*	Tree	Fruit
9	*Amorphophallus gomboczianus*	Herb	Root	25	*Cordia sinensis*	Tree	Fruit
10	*Annona senegalensis*	Tree	Fruit	26	*Cucumis dipsaceus*	Climber	Leaf
11	*Argemone mexicana*	Herb	Seed	27	*Cyperus esculentus*	Herb	Tuber
12	*Balanites aegyptiaca*	Tree	Fruit and leaf	28	*Cyperus rotundus*	Herb	Root
13	*Bidens pilosa*	Herb	Leaf	29	*Datura stramonium*	Herb	Nectar
14	*Carissa spinarum*	Shrub	Fruit	30	*Digera muricata*	Herb	Leaf
15	*Celtis africana*	Tree	Fruit	31	*Diospyros mespiliformis*	Tree	Fruit
16	*Citrullus lanatus*	Climber	Fruit	32	*Dioscorea bulbifera*	Climber	Tuber
33	*Ekebergia capensis*	Tree	Fruit	51	*Pachycymbium laticoronum*	Herb	Young shoot
34	*Eriobotrya japonica*	Tree	Fruit	52	*Pentarrhinum insipidum*	Climber	Leaf
35	*Ficus palmate*	Tree	Fruit and gum	53	*Podocarpus falcatus*	Tree	Fruit oil
36	Ficus *platyphylla*	Tree	Fruit	54	Portulaca *oleracea*	Herb	Leaf and young shoot
37	*Ficus thonningii*	Tree	Fruit	55	*Prosopis juliflora*	Tree	Fruit
38	*Ficus sur*	Herb	Fruit	56	*Rubus apetalus*	Shrub	Fruit
39	*Ficus sychomorous*	Herb	Fruit	57	*Rubus steudneri*	Shrub	Fruit
40	*Justicia flava*	Shrub	Fruit	58	*Solanum nigrum*	Shrub	Leaf
41	*Justicia ladanoides*	Herb	Leaf	59	*Schinus molle*	Shrub	Fruit
42	*Lantana camara*	Herb	Leaf	60	*Tamarindus indica*	Tree	Fruit
43	*Launaea intybacea*	Tree	Fruit	61	*Urtica simensis*	Herb	Leaf and stem
44	*Leptadenia hastata*	Tree	Leaf	62	*Vitellaria paradoxa*	Tree	Seed and fruit
45	*Mimusops kummel*	Shrub	Fruit	63	*Vitex doniana*	Tree	Fruit
46	*Moringa stenopetala*	Tree	Fruit	64	*Ximenia americana*	Tree	Fruit
47	*Morus alba*	Herb	Inflorescence	65	*Ximenia caffra*	Tree	Fruit
48	*Morus mesozygia*	Tree	Fruit	66	*Ziziphus mauritiana*	Tree	Fruit
49	*Ocimum amnericanum*	Herb	Inflorescence	67	*Ziziphus mucronata*	Tree	Fruit
50	*Olea europaea subsp. cuspidata*	Tree	Fruit				

Habits and plant parts used have been adopted from Lulekal et al. (2011).

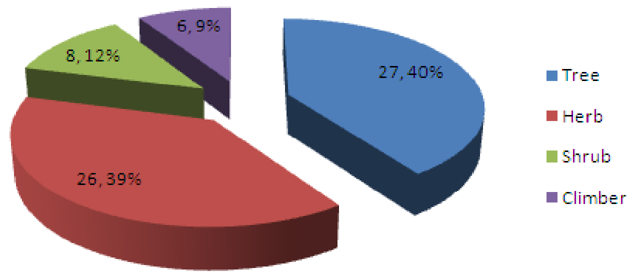

Figure 1. Diversity of wild edible plant growth forms

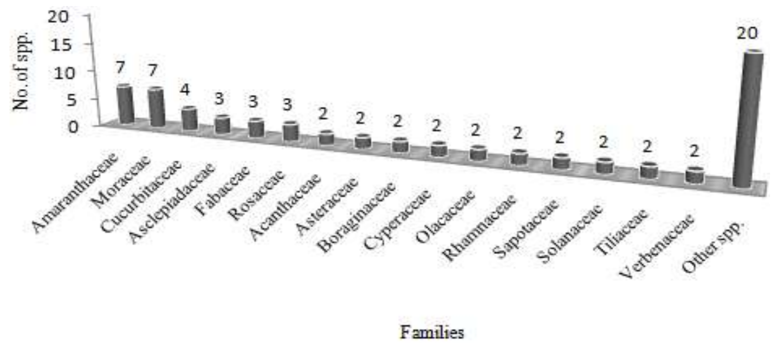

Figure 2. Diversity of families.

endowed with diverse ecosystems that are inhabited by diverse animal, plant and microbial species (EBI, 2014). Ethiopia is one of the top 25 biodiversity-rich countries in the world, and hosts two of the world's 34 biodiversity hotspots, namely: the Eastern Afromontane and the Horn of Africa hotspots (WCMC, 1994). Even though 67 antioxidant WEPs have been investigated through this review, this number might increase significantly with more and more focus on Ethiopian plants.

Diversity of plant families with antioxidant properties

On the topic of each family, species have been reviewed for their antioxidant properties and therefore, the Amaranthaceae and Moraceae comprise the largest number (7 species each), followed by Cucurbitaceae (4 species), Asclepiadaceae, Fabaceae and Rosaceae (3 species, each), Acanthaceae, Asteraceae, Boraginaceae, Cyperaceae, Olacaceae, Rhamnaceae, Sapotaceae Solanaceae, Tliaceae and Verbenaceae (2 species each), and the rest of the families in combination encompass one species (Table 1 and Figure 2).

Plant parts used and studied

In the case of plant parts used, 31 (46.27%) fruits are the dominant edible parts followed by leaves 22 (33%) consumed by people of Ethiopia. The dominance of fruits as edible parts has also been reported in most previous studies undertaken in Ethiopia (Asfaw and Tadesse, 2001; Balemie and Kibebew, 2006; Lulekal et al., 2011). Moreover, other parts or products such as seed (3, 4.5%), inflorescence and tuber (3, 6% each), root, bark, gum, nectar, stem, inflorescence or a combination of two or more of these parts and/or main parts are 7 (10.45) (Figure 3; Table 2). This indicates that the different cultural groups in Ethiopia make use of diverse wild edible plant parts as food sources (Lulekal et al., 2011).

On the other hand, in the case of plant parts studied, within the wild edible plants, leaves 28 (41.79%) followed by fruits 11 (16.42%) are the plant parts most widely studied. Fruit and leaf 9 (13.43%), tuber 5 (7.46%), leaf and stem 3(4.48) and aerial parts 2 (3.00%). Other plant parts and combination of two or more pars such root, pulp, branches, stem bark, leaf and root bark, leaf and flower, leaves and seed, seed pericarp and so on are 9 (13.43%) (Figure 4; Table 1).

Most commonly antioxidant compounds found in plants

The reviews of these antioxidant plants reveal that tannins constitute the largest compounds with 20%

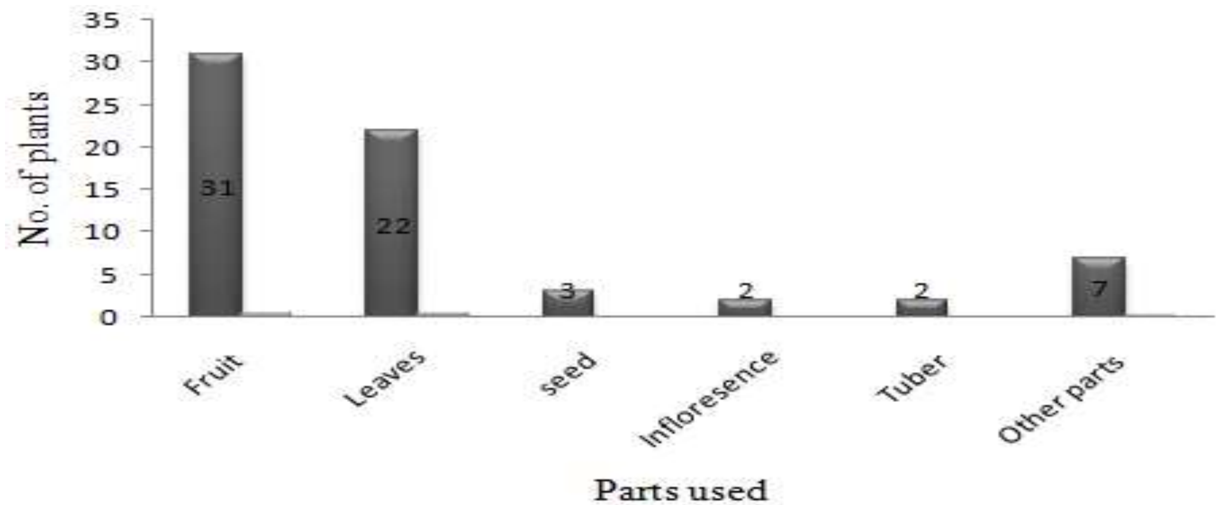

Figure 3. Plant parts used.

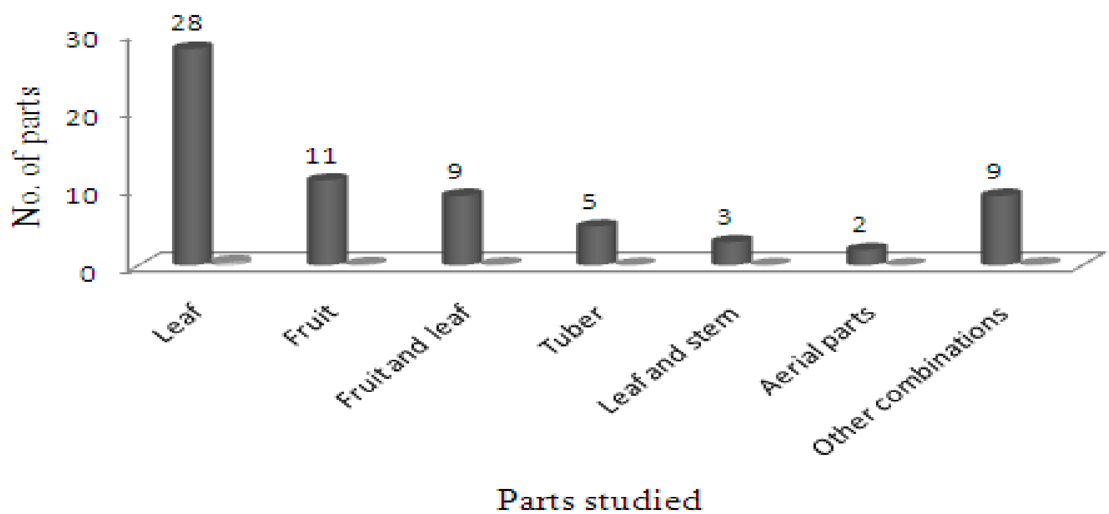

Figure 4. Plant parts studied.

followed by oxalates 17% and phenolics which account for 16% of the chemicals (Figure 5). Phenolics and flavonoids, alkaloids, flavonols, saponins and iridoids account for 13, 13, 7, 5, 5, and 4% respectively of the total scores. The remaining compounds such as steroids, caffeic, phenyl, beta caroteins, phytate, ferulic, terpinoids, and other free radical scavengers score 13% (Figure 5; Table 1). In Table 1, a number of nutrients and/ or minerals like proteins, vitamins, carbohydrates and other bioactive compounds were recorded. The plant compounds recorded in this review have biological activities. For example, flavonoids are one of the most diverse and widespread groups of natural compounds and it has been shown to possess a broad spectrum of chemical and biological activities including radical scavenging properties, antiallergenic, antiviral, anti-inflammatory, and vasodilating actions (Pereira et al., 2009).

Threats and conservation of wild edible plants implicated as sources of antioxidants

According to the world conservation union, over 8,000 plant species worldwide are threatened with extinction, and the number grows daily (Farnsworth, 2007). It has

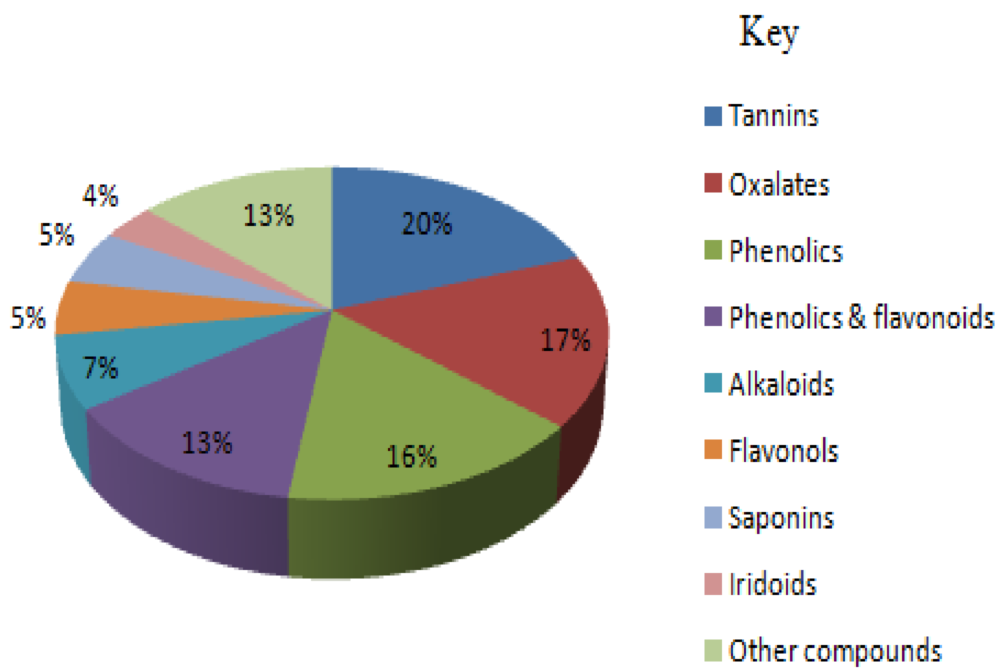

Figure 5. Antioxidant compounds commonly found in wild edible plants.

been postulated that the present rate of global species extinction is 400 times faster than the rate in the geologic past and that this rate is rapidly accelerating (Plotkin, 1995). It was also widely recognized that more species are threatened with the extension now than has ever been before, whether the consideration is on a geological or historical time scale. However, all species are not equally threatened. In addition, the author revealed that the unpleasant conclusion is that the human race is causing one of the first major reductions of global, vascular plant diversity since the origin of life.

In Ethiopia, WEPs are facing threats in their natural habitats from various human activities. The level of impact of these activities varies from place to place (Balemie and Kibebew, 2006). The major threats for WEPs species are overstocking/overgrazing, selective cutting for construction and technology, agricultural land expansion, fuelwood collection and uncontrolled fire setting, firewood and charcoal production, and fencing materials (Wondimu et al., 2006; Balemie and Kibebew, 2006; Assefa and Abebe, 2011; Bahru et al., 2013). The rich and untapped flora, which the indigenous human societies have been using for food, medicine, shelter, etc., needs to be thoroughly investigated and documented through ethnobotany. Tapping indigenous knowledge through ethnobotanical techniques not only helps to know more about the use of the plants concerned but also gives clues to their future development, *in situ* and *ex situ* conservation and sustainable use (Maheshwari, 1988).

With regard to conservation status in Ethiopia, most of the wild species in the areas have no protection. Especially the low land vegetation, which is the potential source of wild edibles, is now shrinking. Nevertheless, very few economic tree species (such as *Cordia africana*) are now managed by some farmers in their farmland as agroforestry tree and/or garden tree. This shows that such management of, and acquisition of economic benefits from species might promote local peoples' interest in conservation and maintenance of such locally important and endangered species (Balemie and Kibebew, 2006). Many researchers tried to give attention to the conservation status of Ethiopian plants. Nevertheless, the measures which were taken in to account the conservation at the country level were not adequate for the effective conservation of biodiversity in different agro-ecological zones. Therefore, it needs supplementary effort by taking into account the community's participation to extend and create awareness on the conservation status of the indigenous knowledge about the plants and the environment itself as well.

Conclusions

The results of the different studies outlined in this review provide a current understanding of the biological effects of antioxidants and their relevance to human health. Polyphenols or polyphenol-rich diets provide significant protection against development and progression of many chronic pathological conditions. It has been confirmed that WEPs contain a wide variety of phenolic compounds which contribute a large amount of antioxidants in the different plant parts to be diet both in Ethiopia and elsewhere in the world. Therefore, food modification through the balanced consumption of wild vegetables, fruits and any part of the plant is likely to be more important and effective than nutritional supplements for the primary prevention of acute diseases.

The present review attempts to explore WEPs species as a source of essential nutrients and bioactive phytochemicals that categorizes it as a functional food. This review compiles traditional, phytochemical and pharmacological data on different plant species. Experimental studies performed on edible and non-edible parts of the plant suggest that the plants possess pharmacological properties like antioxidant, anti-inflammatory, antibacterial, anti-carcinogenic, immunomodulatory and antifungal effects. The presence of phytochemicals with various pharmacological and biological properties also determines the medicinal value of WEPs as useful sources of drugs in ethnomedicine. The antioxidant records on WEPs are therefore an essential investigation tool to further clarify the potential health effects of phytochemical antioxidants in the diet. From this review, it can be concluded that several species of wild plants are used as antioxidants, nutraceuticals or as medicines by the people in Ethiopia and elsewhere in the world. Notably, all of the documented plants have overlapping uses as food and medicine.

Recommendations

Based on the research review results, the following recommendations are forwarded:

(i) Better communications and information exchange, and direct contact with nature in everyday life aspect, is necessary to encourage the consumption of wild edible plants;
(ii) It is suggested that further research needs to be conducted for selecting the different parts of wild edible plants with high antioxidant levels and clarify the importance and role of these antioxidants on the pathogenesis of various diseases;
(iii) The rich world of plants, with thousands of species and varieties, demands study especially, phenolic composition and antioxidant activity of wild and cultivated plants need investigation in Ethiopia;
(iv) The need for identification of possible side effects of using and utilizing these wild plants to limit complications that might occur due to miss use of such plants;
(v) As the review study indicated the high potential of using antioxidant wild edible plants for human benefits, therefore, it deserves further investigations;
(vi) The need to apply conservation measures in different regions of the country should aim at protect endangered species, and this can be done through the establishment of reserved areas, societies, public awareness that encourage plant protection and maintenance of these wild plants; and
(vii) The need for preserving knowledge through documentation and encouragement of people working in the field.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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