CHAPTER I

Introduction

I.1 Introduction

With the rapid increasing of human population, urbanization, industrialization and climate change, the food productions are decreasing day by day in the agriculture field. Moreover, the over uses of hazardous inorganic fertilizers, pesticides and various chemicals in the modern techniques of agriculture are causing many unknown diseases including infertility [1]. Many conventional vegetables and fruits are losing their natural taste and nutritive values due to the over use of inorganic fertilizers. On the other hand due to the poor production of foods, some are suffering from malnutrition and therefore, many people are consuming the ethnic food plants to fulfill the nutritional requirements. These ethnic food plants are not only providing the food, but they also offer many medicinal values. The indigenous tribal people have been consuming wild plants throughout the world since ancient time. The wild edible plants are those which are not cultivated but grow as a weed in the main crop, road side or in the dense forest, riverside and lakes which do not require any proper method of cultivation. These wild plants are collected by the rural people and consumed as vegetable, salad, soup, chutney and can be mixed with many other conventional vegetables. There are numbers of wild edible plants which can be obtained throughout the season and therefore, most of the rural people are directly depending on wild plants to meet their daily food requirements [2]. The wild vegetables contained high sources of minerals, vitamins, proteins, amino acids and sometimes it exceeds the nutritional values of some cultivated green vegetables [3]. Due to the easily accessible of wild vegetables throughout the year, these make a significant contribution to the human nutrition and medicine [4]. These plants improve the household food security and also a source for income generation in the rural areas [5]. Therefore, these wild edible plants are regarded as staple food for indigenous people. These wild plants are also rich in many bioactive compounds having antioxidant and therapeutic properties. Scientific studies have shown that regular eating of fruits and vegetables can avoid most types of cancers occurring on oesophageal, stomach, pancreatic, bladder and cervical [6]. Recently, it has been highlighted that the wild edible plants are the source of 'nutraceuticals' which signifies both nutritional and pharmaceutical values [7]. The wild edible plants are also relatively low in calories, cholesterol-free and provide unique taste and flavour. Besides, they also provide non-nutritive bioactive phytochemicals such as pigments, gums, resins and also have anti-bacterial, hepatoprotective, anti-carcinogenic and many other health beneficial properties [8]. Therefore, the World Health Organization (WHO) recommended consuming atleast 400 g of fruits and vegetables per person per day to protect against diet-related diseases [9, 10]. However, the wild vegetables can also be used for the production of new crops through domestication and also by providing useful genetic resources to the plant breeders [11].

Around the world, the vegetables are the major part of daily food which plays an important role in the balanced diet. Conventional and non conventional green leafy vegetables are excellent sources of minerals which on regular consumption overcome the micronutrient deficiency with minimum cost [12]. Moreover, these vegetables also contain both essential and toxic metals in different concentrations, and have several toxicological effects on the human body [13]. According to Food and Agriculture Organization (FAO), about one billion people depend on wild edible plants in their diets in developing countries [14]. The dietary constituents obtained from these vegetables include moisture, fiber, proteins, fats, ash, organic acids, digestible carbohydrates, minerals and vitamins. There are about fifty types of essential nutrients which are necessary for human health [15] and some of these are listed in the **Table I.1.**

Moisture

About 60% of the body's weight is water which is essential for good health. Daily drinking of 2.2 to 3.0 L water is recommended for an adult human being [16]. Water or moisture is the most abundant component of fresh fruits and leafy vegetables which are up to 95% of the total mass [8]. The moisture of the fruits and vegetables are considered as an excellent source of water and 20% of total water consumption is necessary which is fulfilled by these vegetables [17].

Proteins

These are made of amino acid molecules which represent a major percentage of the human body and carry out many vital activities like cell metabolism, cell growth, differentiation and reproduction etc. [8]. The recommended daily allowance (RDA) for protein intake is 56 g and 46 g/day for men and women, respectively [18].

Table I.1: Different types of nutrients [15].

Nutrients	Types of nutrient	Examples
Macro nutrients	Carbohydrates	Glucose, fructose, sucrose, maltose, starch and dietary fiber etc.
	Proteins	Aliphatic, aromatic, acidic, basic amino acid.
	Fats and oils	Palmitic acid stearic acid Oleic acid, linolenic, α-lenolenic etc.
Mineral nutrients	Macro elements	Na, K, Ca, Mg, P
	Micro elements	Fe, Cu, Zn, Mn, Ni, Se.
Vitamins	Fat soluble	Vitamin A, D, E and K.
	Water soluble	Vitamin B complex and vitamin C.

Lipids

Lipids are the framework of all cellular membranes and can be used as an energy source. They are mainly present as triglycerides (esters of glycerol and fatty acids). Fatty acids present in foods are usually aliphatic and monocarboxylic in nature and they are required to produce cholesterol and steroid hormone that regulate blood pressure, blood clotting and immune and inflammatory responses [8]. The linoleic acid and α-linolenic acids are the most common fatty acids, which are members of the ω-6 and ω-3 fatty acid series. The vegetable oil contains phytosterols which are cholesterol-like steroids. They are absorbed only in trace amounts but inhibit the absorption of intestinal cholesterol [19].

Carbohydrates

These are the major constituents of food measuring up to 50-80% of dry weight. Carbohydrate plays an important role in the structural framework of cells and also serves as storage of energy reserves [20]. Carbohydrates and proteins provide 4 kcal/g of energy, while fats yield 9 kcal/g of energy value and thus for evaluation of total energy, it is multiplied by 4 and 9 respectively [8].

Dietary fibre

It is the non-digestible carbohydrates and lignin present in plants which modulate the intestinal function [18] and helps in weight control [21]. The undigested dietary fibre is fermented in the colon and gives acetic acid, propionic acid and butyric acid which give satiety signaling [22]. Consumption of high fibres is linked to prevention of diseases [18], reduced blood cholesterol, high pressure and lower risk of heart disease [23].

The recommended dietary allowance for macro nutrients given by the National Institute of Nutrition, Indian Council of Medical Research [16] are listed in **Table I.2.**

Table I.2: RDA of macronutrients for human nutrition given by ICMR [16].

Life Stages	Total Water (L/day)	Carbohydrate (g/day)	Total Fibre (g/day)	Fat (g/day)	Protein (g/day)
Infants					
0–6 month	0.7	60	-	31	9.1
6–12 month	0.8	95	-	30	11
Children					
1–3 yrs	1.3	130	19	25	13
4–8 yrs	1.7	130	25	25	19
Males					
9–13 yrs	2.4	130	31	25	34
14–18 yrs	3.3	130	38	25	52
19–50 yrs	3.7	130	38	20	56
> 51 yrs	3.7	130	30	20	56
Females					
9–13 yrs	2.1	130	26	25	34
14–18 yrs	2.3	130	26	25	46
19–50 yrs	2.7	130	25	20	46
> 50 yrs	2.7	130	21	20	46
Pregnancy					
14–18 yrs	3.0	175	28	20	71
19–50 yrs	3.0	175	28	20	71
Lactation					
14–18 yrs	3.8	210	29	20	71
19–50 yrs	3.8	210	29	20	71

I.2 Metals and their importance

The minerals are important elements for the living organisms which help in the normal functioning of life. These are also the constituents of some bioactive molecules, structural components of many proteins and enzymes, regulators of nerve transmission and these can help in muscle contraction, osmotic pressure and water-salt balance in the human body [24]. The mineral malnutrition is one of the most common problems in both developing and developed countries. About two billion people of the world are affected by micronutrient deficiencies resulting in poor health, high rate of mortality and morbidity [25]. It has been estimated that over 60% of the world's populations are iron deficient, 30% are zinc deficient and 15% are selenium deficient; and furthermore, magnesium, calcium and copper deficiencies are also common in several developing countries [26].

Depending on the daily requirement of minerals in the human body, the minerals are classified into macro-elements which are required in more than 100 mg/day and micro-elements are those which are required in less than 100 mg/day. The macro-elements include potassium, sodium, magnesium, calcium, nitrogen and phosphorus whereas the micro-elements include manganese, copper, iron, zinc, cobalt, selenium etc. The macro-elements serve as structural and functional components of the cellular and basal metabolism, and they serve in maintaining of acid-base balance in the organisms [27]. Trace elements and heavy metals have certain adverse health effects [28], thus it is important to determine the levels of these elements in foods and vegetables which are responsible for transferring heavy metals from the environment to the human body. Heavy metals like cadmium, lead and mercury are polluting substances which come from different types of industrial activities and automobiles, which are then mixed or absorbed by soils and taken up or adsorbed by the plants and ultimately enter into the food chain [29]. Consumption of heavy metals causes several adverse health effects with varying extent of severity and symptoms which includes kidney damage, bone decay, neurological and developmental disorders, high blood pressure, lung cancer and many other degenerative diseases [29].

Sodium

Sodium is important for electrolyte balance and blood pressure. Along with potassium, it co-regulates ATP [8]. It also helps in the transportation of metabolites in the body and is one of the major ions present in the extracellular fluid and has the role in maintaining body water. The ratio of potassium and sodium in any food is a significant factor in controlling of hypertension and arteriosclerosis with which the potassium decreases and sodium enhances the blood pressure [30]. The excess amount of sodium is excreted by the body in the form of sweat, whereas deficiency of these minerals may cause diarrhoea and vomiting in children [31].

Potassium

It is an electrolyte that co-regulates ATP with sodium and also regulate acid base metabolism which reduces the risk of developing kidney stones and decreases bone loss with age [32]. It is needed to send nerve impulses and to release energy from fat, carbohydrates and protein and it reduces the risk of cardiovascular diseases [33]. Consumption of higher amount of potassium (4.7 g/day) reduces the chances of cardiovascular disease [34].

Calcium

It is an essential element for bone and tooth formation which is required in higher concentration during adolescence. Milk and dairy products are the main sources of calcium which is followed by cereals and green vegetables. Deficiency of calcium may cause osteoporosis and bone fractures in adults, softening and deformation of the bones (rachitis) in children [35]. It has been found that the high rate of calcium deficiency may cause rickets mostly those in the rural areas [36].

Magnesium

It is an important mineral which is required for protein synthesis, release of energy from storage muscle and regulation of body temperature. It helps in proper functioning of heart and bone formation and also can activate several hundreds of enzymes [8]. Deficiency of magnesium increases the risk for the development of insulin resistance, type-II diabetes mellitus, hypertension, and cardiovascular diseases [37]. Magnesium regulates blood pressure, intracellular calcium, sodium, potassium, and pH as well as left ventricular mass, insulin sensitivity, and arterial compliance [38]. The deficiency of magnesium also causes asthma, angina pectoris, coronary artery disease, cardiac arrhythmias, chronic fatigue syndrome, all types of musculoskeletal disorders, epilepsy, mitral valve prolapse, panic disorder, anxiety, and many other medical and psychiatric conditions [39].

Iron

Iron is the most important and abundant element required for the formation of hemoglobin which carries oxygen and CO_2 in the body. The metabolic principle of copper and iron are closely related to each other and therefore deficiency of copper generates cellular iron deficiency, which results in weakness, reduced cerebral capacity, stunted growth, altered bone mineralization and low immune response [40]. Besides the formation of RBC, it is also required in other heme-containing proteins, electron transport chain, microsomal electron transport proteins and in enzymes such as ribonucleotide reductase, prolyl hydroxylase etc. [40, 41]. It is also an essential cofactor in the synthesis of neurotransmitters such as dopamine, or epinephrine, and serotonin [40]. About 15% of the body's iron is reserved for future requirement and utilized when dietary intake is insufficient [42]. The RDA of iron for adult males and females has been estimated between 8 and 10 mg/day, while for women in reproductive age is recommended for consumption of 15–20 mg/day [18].

Copper

It helps in oxidative defense system which on deficiency gives oxidative stress [43]. It helps in important biochemical and physiological functions and is needed for maintaining health throughout life [44]. It is necessary for the formation of hemoglobin and act as a cofactor for many enzymes including superoxide dismutase, cytochrome-c oxidase, tyrosinase etc. [40]. It is also required for nerve function and energy release [18]. It is a cofactor of many enzymes that catalyze oxidation– reduction reactions in the mitochondrial electron transport system [45] and lysyl oxidase which is involved in collagen biosynthesis [46]. Copper deficiency during pregnancy can cause abnormality in the fetus and persistent neurological and immunological abnormalities in the offspring [43]. It has been recommended that adult males and females should have a dietary intake of 900 μg of copper per day [47].

Zinc

It is a very important micro-element that plays a catalytic or a structural role of about 200 enzymes which are involved in digestion (carboxypeptidase, liver alcohol dehydrogenase, and carbonic anhydrase), reproduction and wound healing [48]. It also plays a role in immune response, maintaining cell membrane integrity, protecting from O_2^{2-} damage i.e. antioxidant, helps in synthesizing RNA and tryptophan, and also act as a precursor of indole-3-acetic acid [8]. It stabilizes the structures of DNA, RNA and the ribosome, and regulates the hormonal metabolism such as insulin or gonadotropin [49]. Zinc deficiency leads to several disorders such as growth retardation, diarrhoea, weak brain function and decreased immune system [49, 18].

Manganese

It is a co-factor for antioxidant enzymes like mitochondrial superoxide dismutase, oxygen-handling enzymes, and also helps in brain functioning, bone structure, and regulation of blood sugar [8]. It acts as a cofactor for numerous vital enzymes e.g. Mn-superoxide dismutase is an antioxidant enzyme that prevents or reduces the oxidative stress, controls the chronic diseases such as diabetes mellitus [50]. Arginase is a manganese dependent enzyme that regulates urea production in the liver and nitric oxide synthase in smooth muscle cells [51]. Other enzymes that require manganese as a cofactor are involved in the metabolism of carbohydrates, amino acids, and cholesterol e.g. transferases, hydrolases, kinases reductases, isomerases, ligases etc. and also involved in the formation of bone and cartilage, and wound healing [52].

Cobalt

It is a transition metal which serves as an integral part of vitamin B_{12}. It is required only 0.1 μg/day for the synthesis of vitamin B_{12} for the human body [53]. However, it also acts as cofactor of enzymes which involved in amino acid metabolism and DNA biosynthesis. The excessive consumption of this element may cause goiter and reduce thyroid activity [54].

Chromium

It is an essential nutrient that increases the insulin action and thus it influences carbohydrate, lipid and protein metabolism [55]. Currently, there is no RDA for chromium, nevertheless the US Food and Nutrition Board [17, 18] derived adequate intakes for this element which is 35 and 25 μg/day for 19–50 year old men and women, respectively. Continuous exposure to chromium may result in liver, kidney and lung damage [55].

Selenium

This is an important element for the formation of selenoproteins and has an active role in modulator of inflammatory and immune responses [56]. The deficiency of selenium causes heart disease, hypothyroidism and a weakened immune system [57].

Due to low concentration of selenium in food, Keshan (a congestion cardiomyopathy in Chinese children) and Kashin-Beck disease of China has been reported [58]. It helps in the protection of body tissues against oxidative stress, defenses against infection, and alters the growth and development [57]. The selenium containing enzymes like glutathione peroxidases and thioredoxin reductase are antioxidants that reduce the lipid peroxidation or hydrogen peroxide release during oxidative stress [59]. It is also essential for male fertility which is required for the production of testosterone and normal development of spermatozoa [60]. Furthermore, it is also associated with greater incidence of depression and other negative thinking such as anxiety, confusion, and hostility [61]. On the other hand, it has a toxic effect in high amount known as selenosis characterized by hair loss and nail brittleness, gastrointestinal problems, skin rash, garlic-breath odour and nervous system abnormalities [59].

Nickel

It is an essential for the catalytic activity of some plant and bacterial enzymes, but the biochemical activity of nickel has not been noticed in the human body [62]. It is also considered a micro-nutrient at low concentration but large doses may be toxic to human being [62]. The enzyme urease contains nickel which is involved in the breakdown of urea to generate ammonia [63]. The effect of nickel is found in the specific responses of the human body such as in the respiratory tract and the skin [64]. Highly sensitive individuals are allergic to it, and with few consumption along with food stuff may cause allergic reaction [62]. The RDA for this element has not been established. However, the oral intake of about 500 μg/day has been reported to worsen hand eczema and suggested that the threshold level of toxicity is less than 500 μg/day [65].

Lead

The lead is toxic heavy metal that contaminates many foodstuff, vegetables and water from the automobile exhaust and industrial effluents. Organic lead compounds are non polar and are more toxic than other forms of lead. During pregnancy, it can also pass through the placenta and affect a growing fetus [66]. It also causes adverse effects on kidney, liver, vascular and immune system [67]. Even at very low concentrations, it can affect the growing brain and the behavioral development in youngsters. Therefore, FAO/WHO [68] considers the maximum tolerable limit of lead for adult human being in between 1.5 and 1.75 mg per day.

Cadmium

This element is considered comparatively toxic because it can damage the kidney and liver function and causes osteoporosis in the long run [69]. The maximum legal limit of the cadmium content in vegetables is given by the European Commission regulation 1881/2006 [70] which is 0.10 mg/kg fresh weight.

Table I.3: RDA of mineral elements in mg/day [17, 18].

	Na	K	Mg	Ca	Fe	Cu	Zn	Mn	Se	Cr
Infant										
0-6 month	120	400	30	200	0.27	0.20	2	0.01	0.02	0.00
6-12 month	370	700	75	260	11	0.22	3	0.60	0.02	0.01
Children										
1-3 yrs	1000	3000	80	700	7	0.34	3	1.20	0.02	0.01
4-8 yrs	1200	3800	130	1000	10	0.44	5	1.50	0.03	0.01
Male										
9-13 yrs	1500	4500	240	1300	8	0.77	8	1.90	0.04	0.02
14-18 yrs	1500	4700	410	1300	15	0.89	11	2.20	0.05	0.03
19-50 yrs	1500	4700	420	1000	18	0.90	11	2.30	0.05	0.03
>51 yrs	1200	4700	420	1200	8	0.90	11	2.30	0.05	0.03
Female										
9-13 yrs	1500	4500	240	1300	8	0.77	8	1.60	0.04	0.02
14-18 yrs	1500	4700	360	1300	15	0.89	9	1.60	0.05	0.02
19-50 yrs	1500	4700	320	1000	18	0.90	8	1.80	0.05	0.02
>51 yrs	1200	4700	320	1200	8	0.90	8	1.80	0.05	0.02
Pregnancy										
14-18 yrs	1500	4700	400	1300	27	1	12	2	0.06	0.03
19-50 yrs	1500	4700	350	1000	27	1	11	2	0.06	0.03
Lactation										
14-18 yrs	1500	5100	360	1300	10	1.30	13	2.60	0.70	0.04
19-50 yrs	1500	5100	310	1000	9	1.30	12	2.60	0.70	0.04

The recommended dietary allowance (RDA) for minerals in different life stages given by the Food and Nutrition Board [17], Institute of Medicine, National Academies [18] is shown in the **Table I.3.** Similarly, the tolerable levels of heavy metals present in some commodities or food products given by the FAO/WHO [68] are presented in the **Table I.4.**

Table I.4: Tolerable limits of heavy metals in foods [68].

Heavy metals	**Food products**	**mg/kg fresh weight**	**Tolerable limit (mg/kg body weight/day)**
Arsenic	Edible fats and oils	0.1	0.015
	Natural mineral water	0.01	
	Rice polished	0.2	
Cadmium	Vegetables of Brassica, bulb and fruiting vegetables	0.05	0.007
	Leafy vegetables, wheat	0.2	
	Pulses, cereal grain, root, tuber, stalk and stem	0.1	
	Rice polished	0.4	
Lead	Vegetables of Brassica, legume, bulb, root and tuber	0.1	0.025
	Leafy vegetables	0.3	

I.3 Antioxidants and their significance

Phytochemicals are the bioactive organic compounds which are naturally present in the plants. These compounds differ extensively in their structure, mechanisms of action, and biological properties [71, 72]. They generally accumulate in all plant cells, but leaves are the major site for their accumulation which may vary according to season, climates and particular growth phases [73]. The most important of these bioactive compounds are phenolic compounds, flavonoids, tannins, steroids, and alkaloids [74]. These bioactive compounds possess many biological properties such as antioxidant, antimicrobial, anticancer and many other activities [75]. Moreover, these bioactive compounds also help in various defense systems of plants against a range of diseases and stress conditions [76].

In cellular metabolism, free radicals such as reactive oxygen species (ROS) and reactive nitrogen species (RNS) are abundantly produced due to aging and external influences like stresses, ionizing radicals, pollutions, and synthetic pesticides [77]. These radicals initiate the lipid and protein oxidation which results in cell structural damage, tissue injury or gene mutation leading to the development of various health disorders such as cancer, Alzheimer's disease, atherosclerosis, diabetes mellitus, hypertension, and ageing processes in the human body [78, 79]. The antioxidants compounds from plants slow down or delay or stop the oxidation processes in the cell by scavenging free radicals or chelating metal ions and thereby protect the human body from oxidative stress related diseases [80]. The free radicals like peroxynitrite ($^{\bullet}ONOO^{\bullet}$) and nitric oxide ($NO^{\bullet}$) and non-free radical species such as like hydrogen peroxide (H_2O_2), nitrous acid (HNO_2) and hydrochlorous acid (HOCl) which are highly reactive and toxic substances formed as by-products in normal cellular metabolism [81]. Different mechanisms by which ROS are produced inside the body are presented in the **Table I.5** [82].

Table I.5: Different types of free radicals produced inside the body [82].

Reactive species	Mechanisms
Superoxide anion ($O_2^{\bullet-}$)	Reduction product of O_2 (One electron reduction), generated by haeme proteins.
Hydrogen peroxide (H_2O_2)	Reduction product of O_2 (Two electron reduction).
H_2O_2	Formed by the addition of proton to O_2.
$^{\bullet}OH$ (Hydroxy radical)	Generated by Fenton's-reaction. It is formed by the reduction of O_2 (3 electron reduction of O_2).
$^{1}O_2$	Singlet oxygen production.
$ROO^{\bullet}$ (Peroxy/ Lipid peroxy radical)	Produced by proton hydrogen abstraction.
$RO^{\bullet}$ (Alkoxy radical)	Produced by organic hydroperoxide.

Depending on the mechanism of action, antioxidants are divided into two main categories *viz.* primary and secondary antioxidants. Primary antioxidants inhibit or retard the oxidation process by scavenging free radicals by donating hydrogen ions to form stable compounds, whereas the secondary antioxidants function by binding with metal ions, scavenging and deactivating singlet oxygen, converting H_2O_2 to non-radical species [83]. To protect against the ROS and RNS, the human body possesses multiple endogenous systems which include both enzymatic and non-enzymatic systems. Among the enzymes, superoxide dismutase, glutathione peroxidase, and catalase protect against the reactive species [84]. The non- enzymatic antioxidants such as glutathione, vitamin A, vitamin C, vitamin E, carotenoids, phytosterols, and polyphenols regulates the cell proliferation and cytotoxicity and also protect lipid peroxidation, glutathione peroxidase activation [85-87]; regulation of thyroid and glucose homeostasis [88]. Though, the living cells have an intracellular defensive mechanism to protect against excessive amounts of ROS or RNS, these mechanisms become insufficient due to aging and external influences like stresses, pollution, ionizing radicals, synthetic pesticides and therefore dietary intake of antioxidants is essential [77].

The dietary antioxidant in fruits and vegetables significantly have many complementary actions like scavenging of free radicals, stimulation of the immune system, regulation of gene expression, hormone metabolism, and antibacterial effects and decreases the bad effects of chemical reactive species on normal physiological functions of human being [89]. It has been reported that free radicals and some ROS and RNS activate and increase the cell death mechanisms such as apoptosis and in severe cases necrosis of cells [90]. The physiological and pathological conditions of the liver, kidney and brain toxicity are also associated with aldehydes and other by-products of lipid peroxidation [91]. Phytochemicals are powerful antioxidants against these reactive species and have a number of potential health benefits [92]. Antioxidants obtained from plant source have advantages as they are less toxic and more effective and low cost [93]. The phenolic compounds possess good antioxidant activity due to their redox properties and can act as reducing agents, hydrogen donors, singlet oxygen scavenger and have the metal chelating properties [94]. Polyphenols compounds are the large group of secondary metabolites which can be categorized into simple phenols, phenolic acids, flavonoids, lignin and tannins, and are responsible for color, bitterness, acerbic taste, flavor, odor and several biological properties including antioxidant [95]. Among these, flavonoids and phenolic acids play an important role in the nutritional, organoleptic, and have many health benefits against chronic diseases, including coronary heart disease, stroke, and cancer [96]. Flavonoids are the smaller part of phenolic compounds which are characterized by the flavan nucleus synthesized by plant tissues for protecting against UV radiation, pathogens, and herbivores [97]. It also contains many derivatives such as flavone, flavonol, isoflavone, flavonone and chalcone which also inhibit lipid oxidation either by scavenging free radicals or by other mechanism which includes quenching of singlet oxygen, chelating of metal ions, and inhibition of lipoxygenase [98]. Similarly flavonoids such as quercetin and kaempferol possess antioxidant activity which reduces the arterial blood pressure [99] and inhibits the growth of human breast carcinoma cells [100]. Phenolic acid, especially the ellagic acid, is also one group of phenolic compounds which has a potential of protective effect against certain cancer type [101]. Other phytochemicals like triterpenoids are derivatives of terpenoids which regulate the transcription and growth factors and intracellular signaling pathways involved in cancer cell proliferation and apoptosis [102]. Alkaloids are also used as antiarrythmic, analgesic, and antihypertensive agents [103], whereas saponins are used as nutraceuticals in traditional medicine preparations [104]. Tannins are water-soluble polyphenols. It has the anti-carcinogenic and antimutagenic potentials due to antioxidant property, and protect against cellular oxidative damage [105]. Similarly, quinone also has various medicinal properties and possesses antitumor, antibacterial, and anti-inflammatory activity [106]. Reducing sugars present in fruits and vegetables work as reducing agents by donating electrons to other molecules which stabilize the oxidation reactions [106]. Vitamin C or ascorbic acid is one of the most powerful antioxidant, which scavenge ROS especially superoxide radical anion, H_2O_2, hydroxyl radical, and singlet oxygen [107]. It has been recommended that the dietary allowances of vitamin C for adult women and men is 75 mg/day and 90 mg/day, respectively and 45 mg/day for the children of 9–12 years old [17, 18]. It can also synthesize the tocopherol (Vitamin E) and also acts as cofactors for many enzymes such as hydroxylases [107].

I.4 Antimicrobial properties of plants

Plants are important sources of natural antimicrobial compounds and antimicrobials of plant origin are more effective in the treatment of infectious diseases than the synthetic drugs which are often associated with several side effects on human health [108, 109]. These healing properties of the plants are due to the presence of the bioactive compounds such as phenolic compounds, flavonoids, steroids, terpenoids, and alkaloids which act numerous modes of action on bacterial cells like degradation of cell wall and leakage of cellular ingredients, depletion of proton motive force, coagulation of cytoplasm, and alteration phospholipids and fatty acid constituents [110, 111]. However, the most common microorganisms responsible for food poisoning are due to contamination with gram-negative bacteria such as *Salmonella typhi*, *Escherichia coli* and *Pseudomonas aeruginosa* [112]. Although the chemical preservative is used to control such kind of food poisoning diseases, it has been reported that the accumulation of chemical residues in the food chain induces microbial resistance and various side effects of these chemicals on human health [113]. In recent times, the researchers around the world have given much attention on plants for the development of new and alternative antimicrobial agents or antibiotics for controlling undesirable pathogens as the plant derived products are safe, easily degradable, and can be used without any adverse effects [114, 115]. Consequently, many indigenous people in different parts of the world have been practising for eradicating several diseases like diarrhoea, bowel, stomachache, bladder disorders, antipyretic, antidiabetic etc. and thus, traditional knowledge is considered as the key for discovering of new medicines [116]. The World Health Organization has also estimated that about 80% population of the world use plant extracts or their active compounds as folk medicine in the traditional method of therapies [117]. Therefore, extraction of natural bioactive compounds from plants assists pharmacological studies leading to the production of more potent drugs with fewer side effects [118]. Various bioactive natural compounds have also been tested against the oral microorganisms to evaluate the antimicrobial activity [119] and among the phytochemicals, polyphenols have the greatest attention due to their diverse biological functions including antimicrobial activity [120]. Similarly, essential oils of bark and leaves of many plants exhibit high antimicrobial activity against aerobic and anaerobic oral microorganisms [121].

I.5 Amino acids and their importance

Amino acids are the building blocks of proteins, and have a significant role in the synthesis of many biochemical compounds like neurotransmitters, hormones, and nucleic acids, and many substances with low molecular weight like polyamines, glutathione, creatine, carnitine, carnosine, thyroid hormones, serotonin, melanin, melatonin, and heme which play a major role in nutrition and medicine [122]. They also participate in cell signalling, gene expression and homeostasis regulation [123], protein phosphorylation, and also have an antioxidant property [122]. They have important roles in metabolic processes as well as for the transport and storage of all the nutrients such as carbohydrates, proteins, fats, minerals, vitamins, and water [124]. However, more than 60% of the proteins required by humans for the growth and development come from plant resources [124] and due to the deficiency of some amino acids in the food stuff, various disorders such as diabetes, insomnia, obesity and arthritis are caused by metabolic disturbances and therefore, the right composition of amino acids in the food may be capable to repair such kind of metabolic deficiencies [125]. There have been more than 700 amino acids discovered from the nature and most of them are α-amino acids. Out of these, 20 amino acids are the only components of proteins that code for the triplet codon of nucleotide [20]. Besides, there are some naturally occurring amino acids such as ornithine and citrulline, carnosine, OH-proline etc. which are not found in proteins [126]. On the basis of their synthesis in the human body, amino acids are broadly classified into essential and non-essential types. The essential amino acids are those which the human body cannot synthesize and, therefore, have to be supplied from the outside as food. The essential and non-essential amino acids are listed in **Table I.6**.

Table I.6: Essential and non-essential amino acids [20].

Non-essential	Conditionally essential	Essential
Alanine	Arginine	Histidine
Asparagine	Cysteine	Isoleucine
Aspertate	Glutamine	Leucine
Glutamate	Glycine	Lysine
Serine	Proline	Methionine
	Tyrosine	Phenylalanine
		Threonine
		Tryptophan
		Valine

The amino acids can be used for the treatment of all types of medical problems such as appendicitis, haemorrhoids, gall bladder stones, heart diseases, obesity and constipation which can be treated by way of consumption of plant foods [127]. The free amino acids and the bound amino acids have the tremendous role in maintaining the physiology of life. Aspartic acid is the precursor for purine, pyrimidine, and asparagine and is involved in detoxification and excretion of ammonia [122, 128]. It also occurs as a physiological compound in the pituitary gland and testis of mammalian which has the role in the regulation of releasing and synthesizing of testosterone hormones [129]. Valine controls the balance of branched chain amino acids, whereas alanine is involved in hepatic autophagy, gluconeogenesis and transamination. Likewise, leucine regulates the protein turnover and gene expression [122, 128]. Glutamic acid is the excellent neurotransmitter for central nervous system, brain and the spinal cord which acts as energy for the brain and helps to correct the physiological imbalances in the body and it is also abundant in muscles which fight against the muscle hypertrophy after a prolonged rest or chronic diseases such as cancer and AIDS [122, 128, 130]. Lysine and threonine maintain the intestinal integrity [131]. Serine is required for the development of the muscles and the maintenance of the immune system. It is also important in the formation of RNA and DNA from the cells [128]**.** Similarly, alanine plays an important role in the transfer of nitrogen and glucose in the body and increases the strength of the immune system by producing antibodies and it also controls toxic substances discharged in the body [122]**.** The proline improves the texture of the skin by the production of collagen and slowing the aging process and improves the problems of cartilage, tendons, muscle of the heart [132].

Arginine is considered as semi-essential amino acid for humans and dietary supplementation is the only way to refill the plasma concentrations of this amino acid [133]. It gives a particular form of amine transamination in which it helps in controlling the metabolic functions of brain and central nervous system [134]. It is also very important in various biochemical processes such as ammonia detoxification, hormone secretion, and immune modulation [135]. This amino acid reduces the toxicity of alcohol and is also frequently used in the treatment of infertility in men [132]. Glycine slows down the muscle degeneration and improves the glycogen storage by releasing glucose to fulfill the energy requirement [132]. Histidine is an antioxidant, which plays an important role in the scavenging of free radicals like hydroxyl radical and singlet oxygen and is also used for the treatment of cardiovascular disease [136]. Methionine and cysteine are the high sulphur containing amino acids and have the antioxidant properties which have important role in preventing the deficiencies of hair cells, skin, and nails [136]. Histidine protects against oily clusters around the liver and the arteries that may cause high pressure and it also detoxifies the harmful effect of lead and other heavy metals [137]. Valine is used in the treatment of liver diseases and gall bladder, and it promotes the intellectual liveliness [137]. Threonine helps in the formation of dental enamel, the collagen and elastin and also takes part in the balanced intake of proteins in the body [137]. The deficiency of isoleucine causes physical and mental disorders, whereas leucine acts with isoleucine and valine to support muscle function, skin and bone formation [132]. Phenylalanine helps in the production of norepinephrine, a chemical substance that transmits the signals between nerve cells in the brain and also regulates human mood, promotes the laziness and vitality, reduces the pain and it is also used in the treatment of arthritis, depression, painful menstruation, migraine, obesity, the Parkinson's disease and schizophrenia [132]. The **Table I.7** shows the essential amino acid requirement patterns for an adult human being given by FAO/WHO/ UNU (2007) [138].

Table I.7: Essential amino acid requirement pattern for adult human [138].

Essential amino acids (EAA)	mg/kg per day	mg/g protein
Histidine	10	15
Isoleucine	20	30
Leucine	39	59
Lysine	30	45
Methionine and Cysteine	15	22
Methionine	10	16
Cysteine	5	6
Phenylalanine and Tyrosine	25	38
Threonine	15	23
Tryptophan	4	6
Valine	26	39
Total EAA	**184**	**277**

I.6 Anti-nutritional factors

In addition to vitamins and minerals, plants also contain some compounds which reduce the nutritional quality in the food of plants and these are known as anti-nutritional factors or compounds. These compounds cause harmful effects to the human health in high concentrations [139]. These are not only lethal toxins, but also disrupt the digestion and absorption of nutrients [140]. They are synthesized in plants by the normal metabolism which inactivates the availability of some nutrients by chelating the proteins, vitamins and minerals and as a whole the plant become less nutrients [141]. There are numbers of anti-nutritional compounds such as lectins, saponins, protease inhibitors, non-protein amino acids, polyphenols, oxalate, phytate, non-starch polysaccharides, tannins, alkaloids and many others [142]. These compounds can be classified into two groups- heat-stable group e.g. phytic acid, condensed tannins, alkaloids, saponins and the other group are heat labile group which includes lectins, cyanogenic glycosides, proteinase inhibitors, and toxic amino acids [143]. As these compounds are heat sensitive, they can be removed by boiling in water, roasting, drying etc. and some are easily soluble in water and therefore, can be removed by soaking and several washing with water, fermenting in certain p^H and other traditional cooking methods [144, 145].

The polyphenols reduces the protein digestibility, either by binding with protein digestive enzymes or directly by binding with proteins [146]. Similarly, some non-starch polysaccharides are involved in the production of flatulence which increases the production of CO_2, H_2 and CH_4 leading to abdominal rumbling, cramps, diarrhoea and nausea [147]. Oxalates are the toxic organic acids which are present in many vegetables and cannot be metabolized by the digestive system of human being and are excreted in the urine. High concentration of oxalic acid in the food binds with minerals and trace elements to form oxalate in the gastrointestinal tract which plays an important role in hyperoxaluria and the formation of calcium oxalate stones in the kidney [148, 149]. The calcium oxalate cannot be absorbed and utilized by the body, thereby causing many diseases including rickets and osteomalacia and it also causes irritation and swelling in the mouth and throat [150]. The inositol phosphates commonly known as phytic acid or phytates are highly negative charge due to the presence of six molecules of a phosphate group, and therefore capable of chelating with divalent cathions such as calcium, iron, magnesium, zinc and copper, as well as starch, protein and enzyme [149, 151]. Similarly, the tannins are the natural phytochemical compounds which are a small group of polyphenols that have the ability to form complexes with proteins, starch and other macromolecules and reduces the nutritional value of foods [152]. Other effects of tannins include undesirable colour in food product due to enzymatic browning reactions, decreased deliciousness of food due to astringency, and it also damage the intestinal mucosa and intervention with iron absorption, glucose and vitamin B_{12} absorption [148]. Tannins are water soluble phenolic compounds with the ability to precipitate the proteins from aqueous solution and it combines with the protein and form tannin-protein complexes which inhibit the digestive enzymes and reduces protein digestibility by the interaction of protein substrate with ionisable iron [147, 152]. It also combines with the saliva and mucosal membrane of the mouth during food mastication [153] and thereby decreases the digestion of proteins and carbohydrates causing growth retardation [154]. Saponins are natural glycosides occurring in different varieties of plants and are soluble in water and methanol, which has toxic properties causing hemolysis of RBC. They interact with cell membranes and disturb the fluidity of cell forming holes and cells become leaky and die [155]. It is also used as the medicine due to the properties of modifying the permeability of the small intestine, and it helps in absorption of specific drugs, acts as neutral steroids and reduces the plasma or serum cholesterol by faecal secretion of bile acid [156]. It has been shown that the triterpene saponins have many pharmaceutical values such as anti-diabetic, anti-inflammatory [157] hepatoprotective [158], and gastro protective [159]. Industrially it is used as precursors for the synthesis of steroids, hormones, contraceptives, anti-inflammatories and diuretics [160]. Saponins are also known as foaming agents due to their surfactant and emulsifier effects which can be used in the making of toothpaste, detergent, soap, shampoo, and hair lotions [161]. Alkaloids are regarded as anti-nutritional compounds because of their action on the nervous system and disturbing electrochemical transmission and it also increases heartbeat, paralysis of heart muscle and its adverse effects can lead to death [162].

I.7 Review of literatures

There are a number of works on the wild edible plants for evaluation of the nutritional qualities, antioxidant and other medicinal properties which have been reported from different parts of the world. The reported studies on the wild edible plants or wild vegetables are highlighted in this Chapter of the Thesis.

The variation of nutritional content of some wild edible aroids of Assam was evaluated by Sarma *et al.* [163] and reported high source of carbohydrate (25.0 ± 0.34%), protein (4.39 ± 0.1%), fat (0.95 ± 0.2%) and flavonoid contents (9.04 ± 0.0 µg QE/mg). The micronutrients like calcium, zinc and iron were reported significantly higher in *Xanthosoma sagittifolium, Colocasia esculenta* and *Alocasia macrorrhiza* as 2.53 µg/g, 0.74 µg/g and 1.05 µg/g, respectively. They also reported highest ascorbic acid (112.87 ± 0.02 mg/100g DW) and total phenolic (34.3 ± 0.12 µg GAE/mg) contents in *Xanthosoma violaceumn*. However, they reported the highest antioxidant activity in *C. esculenta* with DPPH IC_{50} value of 92.26 ± 0.10 µg/mL.

Nutritional values and mineral contents of *Asparagus officinalis, Cordia myxa,* and *Momordica dioica* were investigated by Aberoumand *et al.* [164] and the results showed that the *Asparagus officinalis* had the highest proteins (32.7%) and the mineral contents were comparable with daily recommended dietary allowances given by the Institute of Medicine [18] (**Table I.3**). *Solanum indicum* exhibited the highest iron content (10.6 mg/g), and *Eulophia ochreata* exhibited highest zinc content (3.83 mg/g) in their study.

They also reported the highest phytate content in *Portulaca oleracia* (8.2 mg/g) and the highest phenolic content in *Solanum indicum* (7.00 mg/g).

A similar study on American food plants [165] showed higher amount of minerals like iron (3120 μg/100 g), manganese (7600 μg/100 g), zinc (2060 μg/100 g) and copper (1200 μg/100 g). The highest protein content (14.9%) and calorific values (628 kcal) in *Corylus cornuta* were reported among the ten selected plants and recommended for daily consumption.

Jain *et al*. [166] evaluated some emergency food plants of Central India and reported that among the ten different edible plants, *Oxalis corniculata* contained the highest nutrient value with 12.05% total sugar, 22.28% crude proteins and 23.75% crude lipid contents.

Seal *et al.* [167] evaluated the nutritional potential of five edible plants of Arunachal Pradesh and the results showed that the highest protein content (21.90 ± 0.02%) in *Phytolacca acinosa*, highest carbohydrate (80.88 ± 0.13 %) in *Melodinus khasianus* and total energy content was reported to be ranging from 325.83 ± 2.40 to 409.90 ± 0.66 kcal/100 g in *Phytolacca acinosa* and in *Melodinus khasianus* respectively. Among the minerals, the highest iron, manganese and zinc content was reported highest in *Solanum nigrum* as 1.32 ± 0.001 mg/g, 1.17 ± 0.002 mg/g and 1.53 ± 0.001 mg/g respectively and they showed these nutritional values were higher than that of conventional vegetables and fruits like cauliflower, brinjal cabbage, lettuce, litchi, apple, papaya, mango etc.

The nutritional evaluation of indigenous wild vegetables sold in local markets of Nairobi city of Kenya was reported by Onyango *et al.* [168] and the results showed that *Amaranthus hybridus* had significant nutrient content with total ash (19.2%), crude protein (26.1%), crude fiber (14.7%) and vitamin C (627 mg/100 g). They also mentioned that these vegetables are good sources microelements like zinc (5.5 mg/100 g) and iron (18 mg/100 g). They also reported some anti-nutritional factors like nitrate (732.5 mg/100 g) and oxalates (5830 mg/100 g).

Guerrero *et al.* [169] reported high mineral content in *Amaranthus viridis* and *Verbena officinalis,* whereas small amount of minerals were reported in *Stellaria media*. However, the higher amount of sodium was reported in halophytic species *Crithmum maritimum* (290 ± 6.26 mg/100 g). The highest iron and zinc content was reported in

Amaranthus viridis which were 5.46 ± 0.5 mg/100 g and 1.20 ± 0.10 mg/100 g, respectively.

Parvathi *et al.* [170] investigated the nutritional contents of *Momordica tuberose* and reported that this wild edible plant have high quantity of crude fibre (6.42%), vitamin C (290.00 mg/100 g) and minerals like calcium (72.00 mg/100g), potassium (500.00 mg/100g) and zinc (2.82 mg/100 g) in dry weight basis and recommended for commercialization.

Sotelo *et al.* [171] studied nutritional and anti-nutrient composition of some flowers of wild plants of *Agave salmiana, Aloe vera, Arbutus xalapensis, Cucurbita pepo, Erythrina americana, Erythrina caribaea* and results showed the highest proteins (274 ± 3 g/kg) and dietary fibre (177 ± 2 g/kg) in *Erythrina caribaea*. Moreover, they also reported the limiting amino acid lysine that ranged from 2.24 ± 0.02 mg/g (*Arbutus xalapensis*) to 10.39 ± 0.03 mg/g (*Cucurbita pepo*). However, they reported very negligible amounts of anti-nutritional factors like trypsin inhibitor, hemaglutinnins and alkaloids.

Terangpi *et al.* [172] studied the nutritional contents of some emergency food used by the Karbi tribes of Assam and reported the highest carbohydrates (2.91 ± 0.56 g/100 g) and reducing sugar (0.036 ± 0.36 g/g) in *Dioscorea puber* and *Premna latifolia* had the highest protein (2.12 ± 0.04 g/100 g). The rhizome of *Lassia spinosa* showed high contents of amino acids (8.29 ± 0.04 mg/g) in dry weight basis.

Choudhury *et al.* [173] evaluated the nutritional and the anti-nutritional contents in 25 species of edible plants of Assam and reported that the ash content ranged from 7.8 to 14.7%, crude fibre content varied from 2.5 to 26.10%, crude protein content from 15.77 to 39.38%. They also reported some anti-nutritional factors like saponins that ranged from 0.23 to 0.74%, tannins from 0.37 to 2.82%, phytic acids from 0.03 to 0.32% and oxalate from 0.02 to 0.13% and mentioned that these indigenous vegetables are the sources of functional foods.

Celosia spicata, a leading vegetable in South-west Nigeria was nutritionally evaluated by Ogungbenle *et al.* [174] and reported crude protein content of 10.2 ± 0.01%, carbohydrate of 47.6 ± 0.63% and crude fat of 1.15 ± 0.01%. Among the amino acids, glutamic acid and aspartic acid were found as the most abundant which were 12.8 g/100 g and 8.96 g/100g crude protein, respectively. They also reported some anti-nutritional factors like tannin (97.42 mg/100 g), saponin (4.93 mg/100 g), alkaloid (0.36 mg/100 g), phytate (21.08 mg/100 g) and oxalate (16.53 mg/100 g) in this vegetable.

Similarly, the nutritional content in *Smilax ovalifolia* was evaluated [175] and revealed that dry leaves of this plant contained high amount of crude fibre (256.50 ± 0.338 mg/g), followed by protein (48.23 ± 0.16 mg/g), carbohydrate (31.40 ± 0.009 mg/g) and lipid (20.09 ± 0.10 mg/g) in dry weight basis. This study also showed considerable amounts of vitamin C (0.03 ± 0.008 mg/g) and vitamin E (0.04 ± 0.023 mg/g).

Kedrostis africana, a wild edible medicinal plant of South Africa has been nutritionally evaluated by Unuofin *et al.* [176] and showed that the crude protein content 6.95 ± 0.11%, carbohydrate content of 46.36 ± 0.23 and energy value 223.37 ± 0.88 kcal/100 g. Moreover, the iron content was found 89.90 ± 0.85 mg/100 g DW and zinc content was 4.80 ± 0.28 mg/100 g DW. They have also reported some anti-nutritional factors like phytic acid (2.42 ± 0.17%), oxalate (0.28 ± 0.15%) and saponins (1.94 ± 0.42%).

Satter *et al.* [177] examined the nutritional compositions of some wild edible vegetables in Bangladesh and their results showed highest protein, crude fat and calorific value in *Corchorus capsularis* as 21.98 ± 0.45%, 4.76 ± 0.3% and 371.60 ± 1.16 kcal/100 g, respectively. Among the minerals, the highest iron and zinc content was reported in *Corchorus capsularis* as 73.54 ± 0.25 mg/100 g and 11.14 ± 0.15 mg/100 g, respectively. However, they also reported some toxic heavy metals like lead (0.105 ± 0.004 mg/100 g), chromium (0.77 ± 0.070 mg/100 g) and nickels (0.43 ± 0.030 mg/100 g) in these vegetables.

The six wild edible species of Asteraceae family of Mediterranean was nutritionally evaluated by Herrera *et al.* [178] and reported that the fibre content ranged from 2.3 to 13.4 g/100 g, potassium content ranged from 375 to 1772 mg/100 g and calcium from 16 to 472 mg/100 g which were found to be higher in comparison to many conventional vegetables. Among the edible plants of this family, *Chondrilla juncea* had significant amounts of fibre (13.35 ± 0.70 g/100 g fresh weight) and minerals like manganese (1.45 ± 0.01 mg/100 g fresh weight). Herrera *et al.* [179] also examined phytochemicals and antioxidant properties of underutilized wild leek (*Allium ampeloprasum*) and showed low energy food but good source of fiber (4.23%) and zinc (0.75 mg/100 dry weight) in comparison to its cultivated species. The phenolic and flavonoid contents were found as

5.70 ± 0.62 mg GAE/g extract and 0.86 ± 0.05 mg CAE/g extract, respectively and showed good antioxidant capacity in DPPH assay (IC_{50} 15.12 ± 1.21 mg/mL).

The mineral contents of some edible herbs of Mediterranean like *Cichorium intybus, Sonchus asper* and *Borago officinalis* was studied by Volpe *et al*. [180] and reported that the plants from the polluted area contained high level of heavy metals like As, Cd, Hg, Ni and Pb. The study showed variation of mineral contents in the same sample collected from different locations. They reported that the levels of arsenic content ranged from 1346 µg/kg to 3251 µg/kg, cadmium ranged from 445 µg/kg to 13 µg/kg, mercury content ranged from 1.0 µg kg to 37 µg/kg on dry weight basis.

Bhowmik *et al.* [181] determined the metal contents of some aquatic wild vegetables of Tripura. They reported the highest iron (11.88 ppm) in *Monochoria vaginalis*, highest copper (0.138 ppm) in *Monochoria hastata* and highest zinc (4.87 ppm) in *Neptunia prostrata*. However, the study also revealed the heavy metal contaminants like lead (0.021–0.170 ppm) and cadmium (0.026–0.111 ppm) in those aquatic vegetables.

Saikia *et al.* [182] examined the mineral contents of some wild vegetables of North-East India in fresh and cooked samples and reported that the cooking process significantly ($p<0.05$) decreases the level of macro-elements in most of the vegetables, whereas it has no significant ($p>0.05$) effect on micro-elements of the same vegetables. They reported that the macro-element calcium was the most abundant which ranged from 125.7 to 543.2 mg/100 g, whereas the micro element iron was the most abundant in all the samples which ranged from 6.97 to 22.73 mg/100 g.

Ozcan [183] investigated the mineral contents of 32 different plants of Turkey and reported high amounts of elements like Al, Ba, Ca, Fe, K, Mg, P and S. The concentration of iron ranged from 46.7 mg/kg (*Carum carvi)* to 1229.2 mg/kg (*Lavandula officinalis*); selenium ranged from 0.15 mg/kg (*Satureja hortensis*) to 5.03 mg/kg (*Sinapis alba*) and zinc varied from 5.54 mg/kg (*Rhus coriaria*) to 49.7 mg/kg (*Nigella sativa*). They also reported some heavy metals in these vegetables like lead which ranged from 0.49 to 8.36 mg/kg, vanadium from 0.25 to 19.70 mg/kg, chromium from 3.11 to 19.10 mg/kg and cadmium from 0.01 to 0.04 mg/kg.

The nutritional profiles of some African green leafy vegetables were evaluated [184] and found the highest protein (5.0 g/100 g fresh weight) in *Cleome gynandra* and the highest energy values (319 kJ/100 g fresh weight) in *Corchorus olitorius*. The most important micro-element iron was reported highest (9.2 mg/100 g fresh weight) in *Cucurbita maxima* and highest zinc (1.04 mg/100 g fresh weight) in *Cleome gynandra*. The highest value of vitamin C (10 mg/100 g fresh weight) was reported in *Citrullus lanatus,* vitamin A (537 µg retinol equivalent) was reported in *Amaranthus cruentus* and thiamine (0.08 mg/100 g fresh weight) was reported in *Solanum retroflexum*.

Kawashima *et al.* [185] also evaluated the mineral contents of leafy vegetables consumed in South Brazil and reported that the cooking does not loss any of the minerals. Potassium and calcium were the most abundant in all the samples. The highest level of calcium (7127 ± 517 mg/100 g) was found in *Brassica oleracea,* the highest iron (1.17 ± 0.6 mg/100 g) was found in *Eruca sativa,* and the highest copper (0.27 ± 0.1 mg/100 g) was reported in *Nasturtium officinale.*

It was reported in a study [186] that the vegetables like cereals, starchy tubers and roots, legumes and some fruits had good sources of micro-elements like iron (highest in fermented *Tef enjera,* 34.7 ± 74.1 mg/100 g fresh weight), and Zn (highest in wheat bread, 1.6 ± 0.24 mg/100 g fresh weight). The study also showed that many of these vegetables also contained high levels of phytic acids (highest in wheat bread, 542 ± 11 mg/100 g fresh weight), and tannins (highest in boiled yam spp, 424.17 ± 4.8 mg/100 g fresh weight). Therefore, they suggested doing fermentation of these vegetables to remove such anti-nutritional compounds before consumption.

Glew *et al.* [187] evaluated the nutritional and mineral contents of three edible plants *viz. Sesbania pachycarpa, Crataeva religiosa* and *Brassica oleracea* var. *capitata* from Niger and reported the protein content that ranged from 18.6–36.2% whose essential amino acids content was reported very similar to WHO (2003) standard. Similarly, among the minerals, the calcium was reported as the most abundant and ranged from 23.5–27.4 mg/g dry weight.

Bouba *et al.* [188] analyzed the proximate and mineral compositions of some condiments and their results revealed that all the plants had low moisture content. The highest protein content was reported in *Scorodophleus zenkeri* bark (14%) and highest fat content was reported in *Monodora myristica* (0.53%). The highest calcium (1594.5 mg/100 g) was reported in *Hua gabonii* bark, iron (206.4 mg/100 g) was found in *Echinops giganteus* and selenium (310.0 µg/100 g) was reported in *Scorodophleus zenkeri*. Moreover, they also reported the phenolic content that ranged from 1.05 ± 0.01

to 38.8 ± 0.1 g GAE/100 g in *S. zinkeri* bark and in *Dichrostachys glomerata,* respectively.

The nutritional, minerals and antioxidant contents of some wild edible plants from Kwa-Zulu-Natal were reported by Odhav *et al.* [189]. The highest protein (7 g/100 g fresh weight) was found in *Senna occidentalis,* the highest carbohydrate was found in *Wahlenbergia undulata* (12.8 g/100 g fresh weight) and the highest fat content was found in *Centella asiatica* (2.7 g/100 g fresh weight). The calcium and magnesium were found as the most abundant minerals in their study which ranged from 160 to 3931 mg/100 g dry weight and 193 to 1409 mg/100 g dry weight, respectively. The highest iron (85 mg/100 g dry weight) was reported in *Solanum nigrum,* zinc (109 mg/100 g dry weight) was reported in *Chenopodium album* and highest copper (10 mg/100 g dry weight) was reported in *Bidens pilosa.* Moreover, they also reported that *Protuleca oleracea* had the maximum inhibition (96%) to DPPH radicals in 100 mg/mL concentration of methanol extract.

Borah *et al.* [190] evaluated the mineral contents of some wild edible vegetables of Assam and abundant calcium was found which ranged from 396 mg/g in *Oldenlandia corymbosa* to 875 mg/g in *Amaranthus spinosus* and magnesium content varied from 215 mg/g in *Alternanthera sessilis* to 621 mg/g in *Amaranthus spinosus*. The highest iron content was reported in *Alternanthera sessilis* (25.42 mg/g) and the highest potassium content was reported in *Centella asiatica* (18 mg/g).

Gupta *et al*. [191] examined the nutritional and anti-nutritional contents of some wild edible vegetables and they reported that the protein content ranged from 0.6 g/100 g fresh weight (FW) in *Coleus aromaticus* to 7.1 g/100 g FW in *Cucurbita maxima*. The highest iron content was found in *Digera arvensis* (7.72 mg/100 g FW), zinc content in *Coleus aromaticus* (0.97 mg/100 g FW) and the highest copper content in *Delonix elata* (0.27 mg/100 g FW). They also reported the highest vitamin C (295 mg/100 g), and thiamine (0.33 mg/100 g) in *Delonix elata.* However, the study also reported the presence of some anti-nutritional compounds like oxalate (10–690 mg/100 g FW), tannin (15–1330 mg/100 g FW), and phytate (0.92–13.06 mg/100 g FW).

Renna *et al*. [192] studied the edible plants and reported the highest calcium content of 27.44 ± 3.04 mg/kg dry weight (DW) in *Sinapis arvensis*, the highest manganese content of 155.92 ± 29.26 mg/kg in *Borago officinalis* and highest iron content of 1732.2 ± 446.6 mg/kg in *Papaver rhoeas.* The study also reported the highest concentration of lead (9.76 ± 6.28 g/kg) in *Plantago lagopus,* and cadmium (0.47 ± 0.12 mg/kg) in *Sinapis arvensis* which might be due to the contamination with vehicle exhaust.

The nutrients and bioactive compositions of wild vegetables like *Borago officinalis, Montia fontana, Rorippanasturtium aquaticum, Rumex acetosella,* and *Rumex induratus* were evaluated [193] and among these, *Rumex induratus* was reported to contain the highest levels of sugars (4.97 ± 0.31 g/100 g DW) and ascorbic acid (1064.51 ± 2.56 g/100 g DW). The highest phenolic content was reported in *Rumex acetosella* (141.58 ± 3.67 mg GAE/g extract) and highest flavonoid was found in *Rumex induratus* (89.78 ± 2.81 mg CE/g extract). In the study, the highest antioxidant property was reported both in *Rumex acetosella* and *Rumex induratus* by DPPH radical scavenging assay (IC_{50} 0.03 ± 0.00 mg/mL).

Martins *et al.* [194] analysed the nutritional contents and *in vitro* antioxidant capacities of *Asparagus acutifolius, Bryonia dioca* and *Tamus communis*. The highest proteins (22.4 ± 0.1 g/100 g DW), ash (12.3 ± 0.01 g/100 g DW) and vitamin C (142 ± 12 mg/100 g DW) were reported in *Asparagus acutifolius.* However, in *Tamus communis* the highest carbohydrate (59.5 ± 1.2 g/100 g DW), total energy (440 ± 7 kcal/100 g DW), total phenolic content (TPC) (759 ± 29 mg GAE/g extract) and total flavonoid content (TFC) (150 ± 12 mg CE/g extract) was reported. *Tamus communis* showed the highest antioxidant activity with IC_{50} value of 203 ± 30 μg/mL in DPPH assay.

Khanam *et al.* [195] evaluated the antioxidant activity of some leafy vegetables. Among the flavonoids, isoquercetin content ranged from 3.70 to 19.26 μg/g FW and rutin ranged from 1.60 to 7.89 μg/g FW. Similarly, the total phenolic content was reported in the range of 80.84 ± 4.76 μg ferulic acid equivalent (FAE)/g DW to 317.48 ± 5.05 μg FAE/g DW and flavonoids from 31.67 ± 0.86 μg rutin equivalent (RE)/g DW to 151.77 ± 2.46 to μg RE/g DW.

The total phenolic content (TPC) and total flavonoid content (TFC) in cumin and fennel was studied by Rani *et al.* [196] and reported that the cumin seed contained higher phenolic content (29.5 ± 0.58 mg GAE/g dry extract) and flavonoid content (0.15 ± 0.02 mg QE/g dry extract) in comparison to fennel seed.

Similarly, a comparative study of the antioxidant activity of eleven edible leafy vegetables were reported [197] and higher levels of total phenolics and flavonoid contents were found in *Ipomoea reptans* which were 206 μg GAE/mg DW and 21.0 μg CE/mg DW, respectively. The highest antioxidant activity was reported in *Ipomoea reptans*.

Mata *et al.* [198] studied the aqueous extracts of some spices and the results showed that *Mentha spicata* and *Mentha pulegium* exhibited the highest antioxidant activity in DPPH assay with IC_{50} values of 5.7 ± 0.4 μg/mL and 8.9 ± 0.2 μg/mL, respectively.

Maisuthisakul *et al.* [199] studied Thai indigenous fruits and edible plants. The study showed that the total phenolic content was the highest in berries *viz. Eugenia siamensis* (180.5 ± 1.3 mg GAE/g DW) in comparison to herbs and vegetable plants like *Lasia spinosa* (6.4 ± 0.1 mg GAE/g DW). The study also reported that the chewing plants like *Acacia catechu* having an astringent taste showed a significantly greater value of total phenolic (177.7 ± 0.2 mg GAE/g DW) and flavonoid (41.8 ± 0.2 mg RE/g DW) contents. The highest antioxidant activity was reported in chewing plant *Acacia catechu* with DPPH IC_{50} value of 0.05 ± 0.00 μg/mL followed by edible fruits *Antidesma velutinum* with IC_{50} value 0.07 ± 0.01 μg/mL and *Cleistocalyx operculatus* var. *paniala* with IC_{50} value 0.09 ± 0.00 μg/mL.

Xia *et al.* [200] studied the antioxidant and antimicrobial activities of six edible species of *Sonchus.* The study exhibited that *Sonchus arvensis* contained the highest DPPH and $ABTS^{\bullet+}$ free radical scavenging power with IC_{50} values 15.92 μg/mL and 55.22 μg/mL, respectively. The highest amount of TPC (417.3 ± 38.3 mg GAE/g dry extract) was also reported in *Sonchus arvensis* and TFC (148.5 ± 13.6 mg RE/g of dry extract) was observed in *Sonchus oleraceus*. Moreover, the methanol extract of *S. oleraceus* was also reported with high antimicrobial activity against *E. coli, Salmonella enteric, Staphylococcus aureus* and *Vibrio parahaemolyticus* with zone of inhibition 17.5 ± 1.6 mm, 16 ± 1.2 mm, 14.5 ± 1.2 mm and 10.5 ± 0.6 mm, respectively and MIC values 0.04, 0.05, 0.02 and 0.05 mg/mL, respectively.

Gupta *et al.* [201] studied ethanolic and aqueous extracts of four medicinal plants *viz. Achyranthes aspera, Cynodon dacynodon dactylon, Lantana camara* and *Tagetes patula* for antimicrobial activity against three food borne diseases *viz. Staphylococcus aureus, Pseudomonas aeruginosa* and *Bacillus subtilis*. It was reported that the antibacterial activity of ethanolic extract was most effective against all the tested microorganisms with MIC values ranging from 25 to 125 mg/mL in comparison to aqueous extract.

Similarly, the antibacterial activity of guava leaves, garlic and ginger has been tested by Sapkota *et al*. [202] against some human pathogenic microbes like, *Escherichia coli* and *S. aureus* and they reported that the zone of inhibition ranged from 15.23 to 20.52 mm with all bacteria.

The ethanolic clove extract was reported by Hoque *et al.* [203] as potentially active against *S. aureus* and *Vibrio parahaemolyticus* with MIC values that ranged from 0.5 to 5.5 mg/mL and 0.8 to 5.5 mg/mL, respectively. Likewise, the MIC values of ethanol extract of cinnamon ranged from 1.0 to 3.5 mg/mL and 1.0 to 2.5 mg/mL, respectively for both the microorganisms.

Pandey and Singh [112] also reported the methanolic extract of clove to be highly effective against *S. aureus*, *P. aeruginosa* and *E. coli* with MIC value of 2.31 mg/mL for *E. coli,* 0.385 mg/mL for *Stapylococcus aureus* and 0.01 mg/mL for *Pseudomonas aeruginosa,* respectively.

The antimicrobial activity of *Zingiber officinale, Curcuma longa, Commiphora molmol* and *Pimpinella anisum* against *Streptococcus pyogenes, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa* was investigated [204]. The report exhibited that the methanol extract had higher inhibition zone (19 mm) in comparison to the aqueous extract indicating that the bioactive compounds are more soluble in methanol.

Akinpelu *et al.* [205] studied the antibacterial activity of aqueous and butanolic extracts of *Persea americana* against *Bacillus cereus.* The result showed that the zone of inhibition varied from 10 to 26 mm and MIC value was found as 10 mg/mL and 25 mg/mL for both the extract and MBC value varied from 3.12 to 12.50 mg/mL for both the extract respectively.

A similar work was reported by Venkatesan and Karrunakaran [206] on medicinal plants *Aegle marmelos, Solanum nigrum* and *Cassia fistula* against *S. aureus* and *E. coli.* It was reported that the ethanolic extract of *Cassia fistula* showed the highest zone of inhibition (30.9 mm) against *S. aureus* and the extract of *Solanum nigrum* showed inhibition zone of 30.1 mm against *E. coli.*

Verma *et al*. [207] also studied the antimicrobial activity of punica, citrus and allium against some food borne bacteria like *Salmonella typhi, E. coli, B. cereus* and *S.*

aureus and their study showed that all the extracts were effective against the selected microbes with the zone of inhibition ranging from 9 to 25 mm.

Investigation of antimicrobial activity has been made on ethanol extracts of *Punica granatum, Syzygium aromaticum, Zingiber officinales* and *Thymus vulgaris* by Mostafa *et al.* [208]. The study exhibited strong antimicrobial properties against *Bacillus cereus, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa* and *Salmonella typhi* at 10 mg/mL concentration and the MIC and MBC values ranged from 2.50 to 5.0 mg/mL and 5.0 to 10 mg/mL, respectively.

Mishra *et al.* [209] tested the methanol extracts of some medicinal plants like, *Anogeissus acuminata, Azadirachta indica, Bauhinia variegata, Boerhaavia diffusa* against urinary tract infecting bacteria such as *Enterococcus faecalis, Staphylococcus aureus, Acinetobacter baumannii, Citrobacter freundii,* etc. and reported the zone of inhibition ranging from 25 to 29 mm in all the tested microorganisms. The lowest MIC and MBC values reported were 0.29 mg/mL 0.67 mg/mL, respectively against multi-drug resistance *S. aureus.* However, the higher MIC (3.41 mg/mL) and MBC (4.27 mg/mL) was also reported for other multi-drug resistance bacteria including *E. coli.*

Moran-Palacio *et al.* [210] conducted the determination of the amino acid content of some medicinal plants using high performance liquid chromatography (HPLC) and they reported fifteen amino acids. Out of these, aspartic acid was reported to be ranged from 10.05 ± 0.99 to 38.49 ± 1.34 nM, glutamic acid from 9.82 ± 0.69 to 44.84 ± 1.05 nM, serine from 7.51 ± 0.33 to 29.60 ± 1.27 nM, glycine from 12.63 ± 1.00 to 58.17 ± 2.84 nM, alanine from 11.03 ± 0.77 to 43.05 ± 2.14 nM and leucine from 7.68 ± 0.41 to 38.73 ± 0.60 nM. However, they reported the highest amino acid contents in *Tourneforti hartwegiana* in comparison to the other samples.

Glew *et al.* [211] evaluated the protein quality of some wild edible plants of Cameroun and reported that the amino acids present in these vegetable meets the percentage of that amino acid listed by WHO. Also, the most limiting amino acids lysine was detected higher in *Cadaba furinosa* leaves (7.83 ± 0.58 mg/g DW) and in *Burnatia enneandra* (7.56 ± 0.12 mg/g DW).

Bouba *et al.* [212] investigated twenty different types of edible plants for their amino acid contents and the results showed the total essential amino acid content ranged from 15.85 ± 0.07 (in *Tetrapleura tetraptera*) to 79.81 ± 0.14 mg/100 g protein (in *Scorodophleus zenkeri* bark). The most limiting amino acid lysine was detected highest in *Mondia whitei* (17.1 ± 0.04 mg/100 g protein) and in *Dichrostachys glomerata* (15.32 ± 0.06 mg/100 g protein).

Cassia tora and *Celtis integrifolia* consumed in Nigeria was nutritionally evaluated by Kubmarawa *et al.* [213] and the results showed the protein content of 11.63% in *Cassia tora* and 8.20% in *Celtis intergrifola*. The results revealed the presence of seventeenth different amino acids in varying proportions. It was also reported that the most limiting amino acid lysine was detected as 5.02 g/100 g of protein in *Cassia tora* leaves which was higher than recommended by FAO/WHO indicating the best source of proteins.

Similarly, Omoyeni *et al.* [214] reported seventeen amino acids in the indigenous leafy vegetables of Nigeria. Aspartic acid was reported as the highest in concentration (10.91 g/100 g of protein) while cysteine was noted as the lowest with an average concentration of 0.60 g/100 g of protein in a dry weight basis. They also reported the limiting essential amino acid was methionine with 0.83 g/100 g of protein, while leucine was the most abundant essential amino acid with an average value of 0.74 g/100 g of protein.

Onuegbu *et al.* [215] evaluated the anti-nutritional compounds like oxalate, tannins, saponins, phenols and phytates present in *Mucuna flagellipes* flours and showed the reduction of these compounds up to 82.33%, 42.03%, 19.48%, 3.94% and 45.81% respectively after 60 min of boiling. Similarly, the anti-nutritional contents of four different varieties of cowpea were compared after cooking, soaking, and autoclaving and reported that these compounds were reduced after the processing [216].

The anti-nutritional properties of different varieties of *Phaseolus vulgaris* were reported [217] in which phytate content was the highest in Awash variety (24.07 mg/g) and high tannin and trypsin inhibitors were found in the Beshbesh variety as 28.79 mg/g and 29.27 mg/g, respectively.

The anti-nutritional factors like oxalate, phytate, tannin and saponin were studied in different wild edible fruits [218] and the highest level of oxalate (25.06 ± 6.11 mg/g DW) and tannin (0.136 ± 0.006 TAE g/g DW) was reported in *Aegle marmelos*. The highest saponin (0.18 ± 0.07 g/g DW) was reported in *Ficus hispida*.

Similarly, the anti-nutritional factors of some wild edible fruits *viz. Grewia tiliifolia, Meyna laxiflora, Cordia dichotoma* etc. were studied [219]. The phytate content was reported the highest (0.7 ± 0.2 %) in *Ficus racemosa*, highest oxalate (2.5

± 0.36%) in *Ziziphus rugosa*, highest tannin (1.96 ± 0.03%) in *Flacourtia indica* and the highest saponin (53.36 ± 0.47 %) in *Meyna laxiflora*.

Agbaire *et al.* [220] also determined the anti-nutritional factors present in wild leafy vegetables of Nigeria. The results showed that the oxalate concentration ranged from 0.09 ± 0.01 µg/g (*Androgen citrates*) to 2.60 ± 0.45 µg/g (*Talinum triangulare*), phytate from 4.12 ± 0.45 µg/g (*Amaranthus hybridus*) to 13.00 ± 0.40 µg/g (*Ocimum gratissimum*), and tannin from 0.04 ± 0.01 µg/g (*Vernonia amygdalina*) to 0.26 ± 0.03 µg/g (*Ocimum gratissimum*) in dry weight basis.

The biological properties of some reported wild edible plants and vegetables along with the bioactive compounds present are summarized briefly in **Table I.8**.

Table I.8: Biological properties of some reported wild edible plants and vegetables

Plants	Bioactive compounds	Biological properties	References
Gymnema sylvestre	Flavonoids, tannin, phenolics and gymnemic acid	Antimicrobial activity, gastric protection against gastric ulcer, anti-allergic, anti-stress and cytoprotective activity	[221]
Agave durangensi	Favonoids	Antioxidant	[222]
Malvae herba, Rosmarini folium, Bursae pastoris herba, Visci albi herba	Phenolics	Antioxidants	[223]
Allium roseum	Polyphenols	Antioxidant and antibacterial	[224]
Oroxylum indicum	Phenolics	Antioxidant and antibacterial	[225]
Murraya koenigii	Essential oils	Antibacterial and antioxidant	[226]
Fagopyrum esculentum	Anthocyanins, carotenoids, rutin, vitamin E	Antioxidant	[227]
Centella asiatica, Eugenia	Phenolic compounds	Antioxidant	[228]

polyantha, Polygonium hydropiper			
Amaranthus hybridus, Cleome gynandra, Bidens pilosa, Corchorus olitorius, Galinsoga parviflora,	Favonoids, proanthocyanidins, tannins	Prevention of cardiovascular and other chronic diseases.	[92]
Melissae folium, Spiraea herba, Thymi herba, Uvae ursi folium, Salicis cortex	Phenolics	Antioxidant	[223]
Cryptotaenia japonica, Amaranthus tricolor, Brassica rapa, Lactuca sativa	Phenolic acids, flavonoids	Antioxidant	[229]
Bauhinia variegata	Flavonoids	Antibacterial, antioxidant, and anticancer	[230]
Viguiera arenaria	Diterpines	Antibacterial activity	[231]
Calpurnia aurea	Polyphenols	Antidiarrhoeal and antimicrobial	[232]
Microcos paniculata	Alkaloids, saponins, tannins, flavonoids and triterpenoids.	Anti-inflammatory, analgesic and antipyretic activities	[233]
Habenaria edgeworthii, Habenaria intermedi, Roscoea procera	Alkaloids, phenolic, flavonoids, tannins	Antioxidant	[234]
Mimosa pudica	Phenolics	Antioxidant, antihelmintic, antidiarhoeal	[235] [236]
Farfarae folium, Basilici herba, Majoranae folium, Hederae folium, Teraxaci folium, Sanbuci flos, Montana herba	Phenolics	Antioxidant	[223]
Oleae folium, Betulae folium, Satureiae herba, Chellidonii herba	Phenolics	Antioxidant	[223]

Ageratum conyzoides, Bidens pilosa, Brassica campestris, Camellia japonica, Ericaceae rhododendron	Phenolics	Antioxidant	[237]
Ipomoea cairica, Jatropha integerrima, Lantana camara, Oxalis corymbosa, Phaseolus vulgaris, Rhoeo discolor, Iris japonica	Phenolics	Antioxidant	[237]
Amaranthus retroflexus, Beta vulgaris, Brassica oleracea, Chaerophyllum byzantinum.	Phenolics, flavonoids, anthocyanins	Antioxidant	[238]
Polygonum amphibium, Rumex acetosella, Similax excels, Trachystemon orientalis	Phenolics, flavonoids, anthocyanins	Antioxidant	[238]
Eryngium foetidum, Oenanthe stolonifera, Boesenbergia pandurata, Dregea volubilis, Neptunia oleracea	Vit C, Vit E, carotenes, xanthophylls, Tannins, phenolics	Antioxidant, antipyretic, laxative, digestive tonic, anti-hyperglycemia	[239]
Asteracantha longifolia, Bacopa monnieri, Bauhinia racemosa, Centella asiatica, Chenopodium album, Ipomoea reptans	Flavonoids polyphenols	Antioxidant	[197]
Enhydra fluctuans, Moringa oleifera, Nyctanthes arbortristis, Paederia foetida	Flavonoids polyphenols	Antioxidant	[197]
Artemisia vulgaris, Careya	Polyphenol	Antioxidant, antidiabetic	[240]

arborea, Ficus recemosa, Horsfieldia amygdalina, Hooutuynia cordata			
Eryngium foetidum, Paederia lanuginose, Sponius pinnata, Premna corymbosa, Polygonum odoratum, Ipomea aquatica.	Polyphenol	Antioxidant, antidiabetic	[240]
Antidesma acidum	Alkaloids like clauszoline, mukonal, 7-methoxymukonal, heptaphylin, phenolic, flavonoids	Cytotoxic activity, antioxidant	[241, 242]
Blumea lanceolaria	Polyphenol	Antioxidant, antimicrobial	[240, 243]
Drymaria cordata	Not mentioned	analgesic antipyretic, anxiolytic, antibacterial, cytotoxic activity	[244-246]
Enhydra fluctuans	Polyphenol, flavonoids	Antioxidant, antidiabetic, anticancer, anti-diarrhoeal, hepatoprotective	[240, 247-249]
Eryngium foetidum	Carotinoids, polyphenols-lutein, caffeic acid, chlorogenic acid, kaempferol.	Antioxidant, anti-inflamatory, cytotoxicity, anti-helicobacter	[250, 251]
Lippia javanica	Phenolics, flavonoids, proanthocyanidin	Anti-inflamatory, antimicrobial	[252]
Melotria perpusilla	Flavonoids	Antidiabetic	[253, 254]
Oenanthe javanica	Crude ethanol extract	Antioxidant, protects against neuronal damage	
Polygonum chinensis	Crude ethanol	Anti-diarhoeal,	[255]

	extract	antibacterial	
Sphenoclea zeylanica	Methanolic extract	Antibacterial	[256-258]
Sphaeranthus indicus	Crude ethanol extract	Anti-diabetic, antihyperlipidemic antioxidant, anti-inflammatory, anti-proliferative	[257]
Stellaria media	Phenolics, mineral contents	Antioxidants, antifungal	[259]
Tetrastigma anguistifolium	Hydro alcoholic extract	Anti-diabetic, cytotoxicity	[260]

I.8 North Eastern region of India

The North Eastern (NE) region of India is one of the major hotspots of the world which is also known as the Eastern Himalayas. This hotspot is known for its high ethnic and biological biodiversity which also includes eight different states *viz.* Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Sikkim. Assam (21°34$^{/}$N to 29°50$^{/}$N latitude and 87°32$^{/}$E to 97°50$^{/}$E longitude) is the second largest state of NE India and it covers an area of 262,060 sq. km and out of which about 23,688 sq. km area is covered by the forest [261]. The state is also a part of mega diversity of India, where various seasonal epidemic and huge number of medicinal and wild vegetable plants are available. Out of 450 tribal communities in India, more than 50% is inhabited in NE region of India [262]. Among the total population of Assam, about 11% are indigenous tribal community which include Bodo, Mishing, Deori, Karbi, Sonowal–Kachari, Rabha, Dimasa, *etc*. The Bodo is the largest tribes among all the tribes in the state and they directly or indirectly depend on the forest for their daily life. The indigenous tribal communities of the region have vast traditional knowledge on the utilization of forest based plants as food and medicinal products in various ways [263]. The collection and consumption of wild plants are one of the cultural practices among these people. The local healers among the tribal people used to prepare many folk medicines through their traditional knowledge. Moreover, many wild plants are also occasionally used in religious and cultural ceremonies among the Bodo tribes of Assam [264]. The Bodoland Territorial Area Districts (BTAD) is one particular area that occurs in the Northern part of Brahmaputra valley of Assam. It comprises four districts *viz.* Kokrajhar, Baksa, Chirang and Udalguri where majority of the inhabitants are Bodo tribes. It covers 3539.95 sq. km area of forest with international boundary of Bhutan towards the North. The Bodos inhabit in this Sub-Himalayan tract with vast knowledge of vegetables and herbal medicines for healing and curing of various ailments [265].

Therefore, researchers should give attentions to study each and every plant species used by different ethnic groups of this region and to explore their potentiality for use of foods and medicines.

I.9 Objectives

Considering the safety aspects of wild edible plants and frequent consumption of these plants by the Bodos of Assam, the focused objectives of the work and under which the parameters are

(a) Determination of proximate composition of wild edible plants.
(b) Determination of mineral contents.
(c) Analysis of phytochemicals and *in vitro* antioxidant activity.
(d) Antimicrobial activity study.
(e) Evaluation of amino acid composition.
(f) Determination of anti-nutritional contents.

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