CHAPTER I

Introduction

I.1 Introduction

Wild edible fruits which constitute an excellent source of nutritional and medicinal property have been used for many centuries by the indigenous people of different localities. Edible wild fruits play a significant role in supplementing the nutritional requirement of a rural population and have great economic potential for the rural community. Edible fruits harvested by the rural community from the natural habitat are often sold in rural market and it becomes an important part of their income source also. Edible wild fruits are common food resources consumed frequently in rural communities. In addition to the role of meeting nutrient intake levels, consumption of wild fruits have various health benefits against chronic diseases including cardiovascular diseases, diabetes, obesity and certain types of cancer [1]. Some edible wild plants have been demonstrated that in many cases the nutritive value of wild plants are comparable and in some cases they have better nutritional values than cultivated fruits [2, 3]. As a result, in recent years, a growing interest among the researchers has emerged to assess various wild edible plants for their nutritional features [4]. Like the domesticated fruits and vegetables, wild indigenous fruits are also rich sources of various dietary fibres, vitamins, minerals and bioactive compounds which are essential for the proper maintenance of human health [5]. Traditionally, various fruits have been used as folk medicine for several thousand years [6]. Besides the fruits, the plant parts such as bark, leaves, sap, stem, root and twig are used as ingredients for traditional medicine. These parts could be of great interest for the use of folk medicines by local communities for treating several diseases including cough, fever, asthma, skin diseases, indigestion, and diarrhea [7]. In modern medicine, bioactive compounds isolated from different parts of the plant including fruits have been further employed for their nutraceuticals and medicinal ingredients [8].

In developing countries, numerous types of edible wild plants are exploited as sources of food to provide an adequate level of nutrition including protein, carbohydrates, fat, vitamins, and minerals to the local populace [4]. According to the report of Food and Agricultural Organization (FAO), at least one billion people in the world are thought to use wild foods in their diet [9]. About 150 species of wild plants have been identified as an emergency sources of food in India, Malaysia and Thailand [10]. In other African nations, edible wild plants contribute a greater share of the diet than cultivated fruits [11]. In South Africa, approximately 1400 species of edible plants are used, while in the Sahel region, about 200 wild food items were recognized and being used by the rural population [12]. In most of the reports, it was emphasized that the nutritional composition of unconventional plant foods could be comparable to or even sometimes superior to the domesticated cultivars [13]. It is important to note that the incorporation of semi-cultivated and edible wild plants resources could be beneficial to nutrition of marginal populations or to certain vulnerable groups within the populations, especially in developing countries where climatic change and poverty could lead havoc to the rural population. In the past decades, numerous studies have revealed that the edible wild fruits provide nutritional and medicinal needs and suggested that the kinds and amounts of dietary fibres, minerals and organic acids are important factors for determining whether such ingredients of wild fruits and vegetables are potential sources for dietary health enhancing [14].

Despite the achievement of food self-sufficiency at the national level, the country could not solve the problem of household food insecurity particularly in rural areas. A considerable proportion of rural population still suffers from hunger and undernourished. People living in most of the remote and rural areas do not produce adequate food grains to meet annual food requirement and at times food supplies are not easily available. Therefore, a large share of rural population is meeting their nutritional requirement through non-conventional means, by consuming several wild plants and animal resources [15]. Although only three major cereal crops *viz*. rice, wheat and maize provide around 50% of human energy intake, some 7000 species are used, or have been used for human food [16]. Nutrition is most absolutely necessary for normal functioning of body. Nutrients are the substances from food assuring a normal development of the biological processes in the human body and participate in the metabolic processes. Nutrients can be grouped into six major classes *viz*. carbohydrates, proteins, lipids, minerals, vitamins and water. The first five are called essential nutrients. Carbohydrates, protein and fats are considered macronutrients because these nutrients are needed in larger. Whereas vitamins and minerals are called micronutrients as these are needed in very small quantities. Besides nutrients, there are many other chemical substances that do not fit the classical definition of a nutrient and these include enzymes, dietary fibres and phytochemicals [17]. The recommended dietary allowances of total water and macronutrients are displayed in **Table I.1** [18].

Table I.1: Recommended dietary allowances for total water and macronutrients

Life stage groups	Total water (L/d)	Carbohydrate (g/d)	Total fibre (g/d)	Fat (g/d)	Protein (g/d)
Infants					
0-6 months	0.7	60	ND	31	9.1
7-12 months	0.8	95	ND	30	11
Children					
1–3 y	1.3	130	19	ND	13
4–8 y	1.7	130	25	ND	19
Males					
9–13 y	2.4	130	31	ND	34
14–18 y	3.3	130	38	ND	52
19–30 y	3.7	130	38	ND	56
31–50 y	3.7	130	38	ND	56
51–70 y	3.7	130	30	ND	56
> 70 y	3.7	130	30	ND	56
Females					
9–13 y	2.1	130	26	ND	34
14–18 y	2.3	130	26	ND	46
19–30 y	2.7	130	25	ND	46
31–50 y	2.7	130	25	ND	46
51–70 y	2.7	130	21	ND	46
> 70 y	2.7	130	21	ND	46
Pregnancy					
14–18 y	3.0	175	28	ND	71
19–30 y	3.0	175	28	ND	71
31–50 y	3.0	175	28	ND	71
Lactation					
14–18 y	3.8	210	29	ND	71
19–30 y	3.8	210	29	ND	71
31–50 y	3.8	210	29	ND	71

d = day; ND = Not determinable

1.2 Importance of fruits for human health and disease prevention

Fruits and vegetables play very important roles in human nutrition especially as the good sources of minerals, dietary fibre, vitamin C, thiamine, pyridoxine, folic acid and niacin [19]. In US, consumption of fruits and vegetables contribute to an estimated intake of 91% of vitamin C, 27% of vitamin B6, 30% of folic acid, 48% of vitamin A, 17% of thiamine and 15% of niacin. Intake of fruits and vegetables also supply 19% of iron, 16% of magnesium and 9% of calories [20]. Other essential nutrients supplied by fruits and vegetables include zinc, riboflavin, calcium, potassium and phosphorus. Some constituents of fruits and vegetables are good sources of phytochemicals that function as antioxidants, anti-inflammatory agents and phytoestrogens and other protective mechanisms [21]. As the antioxidant capacity of fruits and vegetables varies, it is suggested to consume a variety of them rather than limiting consumption to a few with the highest antioxidant capacity. The USDA [20] encourages consumers to take at least three servings of vegetables and at least two servings of fruits per day. However, in some countries, consumers are suggested to eat at least 10 servings of fruits and vegetables per day. Southon [22] showed that high intakes of carotenoid-rich fruits and vegetables was more effective than carotenoid dietary supplements in increasing LDL oxidation resistance, lowering DNA damage, and inducing higher repair activity in human volunteers who participated in a study conducted in France, Netherlands, Italy and Spain. In another study, addition of antioxidant (vitamins A, C and E) dietary supplements into the diet of cancer treatment patients, who were taking a balanced diet of fruits and vegetables, negatively impacted their radio-and chemotherapies [23].

It was reported that adequate intake of fruits and vegetables are associated with a reduced risk of variety of chronic diseases including obesity [24]. He *et al*. [25] also conducted a study in respect of fruit and vegetable consumption and their effects on weight management and the study revealed that an increased consumption of fruit and vegetable was associated with a 24% lower risk of becoming obese. Ness and Powles [26] reported about fruits and vegetables intake and the development of coronary heart disease and the study showed a significant inverse association between the amount of fruits and vegetables intake and the incidence of coronary heart disease.

Alonso *et al*. [27] also reported an inverse association between fruit and vegetable intake and decreased blood pressure. Galeone *et al*. [28] showed that adequate consumption of fruits and vegetables significantly decreased the risk of lung cancer and the reduced risk was significantly evident in smokers as well as non-smokers. Adequate consumption of fruits and vegetables about 3 to 9 servings/day has been found to decrease urinary calcium loss of about 50 mg/day and lower biochemical markers of bone turnover especially bone resorption [29]. In a study conducted by He *et al*. [25], it was reported that a significant lower risk of stroke development among those with the highest consumption of fruits and vegetables. Lock *et al*. [30] also showed that increasing intake of fruit and vegetable by 600 g per day could reduce the global burden of stroke by 19% and decrease the risk of CHD by 31% respectively. Moreover, Habauzit *et al*. [31] showed that fruits containing high amount of anthocyanins, flavonols and procyanidins such as berries, grapes and pomegranate are effective at decreasing cardiovascular risk while citrus fruits and apples had a moderate effect on blood lipid level and blood pressure. An increased intake of carotenoid-rich fruits and vegetables maintain the cholesterol level in blood since they reduce oxidative damage and cause an increase in LDL oxidation resistance [22]. High intakes of fruits and vegetables have also been suggested to prevent osteoporosis in adults because of their rich sources of calcium and other vitamins which are vital in bone health [32]. The high fibre content of fruits and vegetables play a role in calcium absorption and may reduce the ‘acid load’ of the diet enhancing bone formation and suppressing bone resorption which consequently result in greater bone strength [33]. In addition, fruits have been suggested to prevent obesity since they add up to dietary variety both between and within food groups and palatability to the diet which has been revealed to be an important predictor of body fat [34].

I.3 Minerals

Minerals present in plants are of great importance in human diet, although they constitute only 4–6% of human body [35]. Some major minerals (macro-elements) are required in amounts greater than 100 mg per day which represent 1% or less of body-weight [36, 37]. The essential macro-minerals include calcium, potassium, sodium, phosphorous, sulphur, magnesium and chloride. Trace elements such as zinc, iron, copper, manganese, selenium, iodine and molybdenum are considered essential and are normally required by the human body in much smaller quantities, generally less than 100 mg/day, which represents only 0.01% of the body-weight [37].

The major minerals play a vital role in acid-base equilibrium of the body, serve as structural components of body tissues and function in cellular and basal metabolism. In biological systems, micro-elements are mainly bound to proteins, forming metallo-proteins or bound to smaller molecules such as phytates, phosphates, polyphenols and other chelating compounds. In metallo-proteins form, these elements are the essential parts of enzymatic systems, having structural functions or help in transport of the bound proteins to their target sites in the organism. Elements like chromium, cobalt, copper and nickel are the essential parts of biological structures but may also be toxic at higher concentrations. Other elements like arsenic, cadmium and lead have well-known toxic roles in different biochemical reactions [38].

Recent research had shown that optimal intakes of elements such as sodium, potassium, magnesium, calcium, manganese, copper, zinc and iodine could reduce individual risk factors including those related to cardiovascular disease for both human beings and animals [39]. Ca together with K, phosphorous and Mg is important for the growth of bones and teeth. This element functions on muscles and cell membranes by regulating endo and exo-enzymes [36]. Na and K are very significant body minerals and important to both cellular and electrical function. Na is excreted through human sweat. Diarrhea and vomiting may lead to the loss of Na and K. Tea, fruits, vegetables and coffee are chief sources of Na and K. The minimum recommended daily intake of Na and K are 2.4 g and 3.5 g respectively [40]. Adequate intake of dietary minerals is vital for health and wellness and the **Table I.2** shows the recommended dietary allowances of some of the elements [18]. Throughout the world, there is growing interest in the role of dietary minerals in optimizing health, and in prevention or treatment of several diseases. Micronutrient deficiencies continue to be major problem and are highly prevalent in low and middle income countries and such deficiencies of essential micronutrients found in fruits can increase the risk of illness from infectious diseases by reducing immune and non-immune defenses [41].

Around the world different techniques have been carried out, from time to time, for the determination of trace elements by using differential pulse anodic stripping voltammetric technique, instrumental neutron activation analysis, stripping potentiometry, atomic fluorescence spectrometry, capillary zone electrophoresis, inductively coupled plasma emission spectroscopy, flow injection spectrometric methods, inductively coupled plasma optical emission spectrometry, flame atomic absorption spectrometry, inductively coupled plasma mass spectrometry [32, 42]. ICP-MS technology has been widely used for the analyses of trace elements in foods with satisfactory results [42, 43].

Table I.2: Recommended dietary allowances of elements [18]

Life stage groups	Na (g/d)	K (g/d)	Mg (mg/d)	Ca (mg/d)	Fe (mg/d)	Cu (mg/d)	Mn (mg/d)	Zn (mg/d)
Infants								
0-6 months	0.12	0.4	30	200	0.27	200	0.003	2
7-12 months	0.37	0.7	75	260	11	220	0.6	3
Children								
1–3 y	1	3	80	700	7	340	1.2	3
4–8 y	1.2	3.8	130	1000	10	440	1.5	5
Males								
9–13 y	1.5	4.5	240	1300	8	700	1.9	8
14–18 y	1.5	4.7	410	1300	11	890	2.2	11
19–30 y	1.5	4.7	400	1000	8	900	2.3	11
31–50 y	1.5	4.7	420	1000	8	900	2.3	11
51–70 y	1.3	4.7	420	1000	8	900	2.3	11
> 70 y	1.2	4.7	420	1200	8	900	2.3	11
Females								
9–13 y	1.5	4.5	240	1300	8	700	1.6	8
14–18 y	1.5	4.7	360	1300	15	890	1.6	9
19–30 y	1.5	4.7	310	1000	18	900	1.8	8
31–50 y	1.5	4.7	320	1000	18	900	1.8	8
51–70 y	1.3	4.7	320	1200	8	900	1.8	8
> 70 y	1.2	4.7	320	1200	8	900	1.8	8
Pregnancy								
14–18 y	1.5	4.7	400	1300	27	1000	2	12
19–30 y	1.5	4.7	350	1000	27	1000	2	11
31–50 y	1.5	4.7	360	1000	27	1000	2	11
Lactation								
14–18 y	1.5	5.1	360	1300	10	1300	2.6	13
19–30 y	1.5	5.1	310	1000	9	1300	2.6	12
31–50 y	1.5	5.1	320	1000	9	1300	2.6	12

d = day

I.3.1 Macro-elements

Sodium

Sodium is the primary cation found in extracellular fluids. It regulates acid-base balance and plasma volume which is involved in the maintenance of normal osmotic pressure of the body fluids, preserves irritability of muscles and cell permeability, activates nerve and muscle function and involved in Na^+/K^+ ATPase [44]. It also plays a vital role in maintenance of membrane potentials, conduction and transmission of nerve impulse and the absorption of monosaccharides, pyrimidines, amino acids and bile salts. Low level of sodium in the serum or excess water in relation to the amount of sodium is hyponatremia and this occurs in acute Addison's disease, excessive diarrhea or vomiting, nephrosis, severe burns and intestinal obstruction [45]. Excess of sodium concentration in the serum is called hypernatremia and this occurs in Cushion's syndrome, administration of adrenocorticotropic hormone (ACTH), diabetes insipidus and renal failure [46].

Potassium

Potassium is the major intracellular cation, required for normal cellular function in the body. Dietary potassium can lower blood pressure blunting the effects of NaCl. Inadequate intake of potassium has long been found to be associated with higher blood pressure [47]. It also regulates heartbeat, assists in muscle contraction and is required to send nerve impulses as well as in releasing energy from fat, carbohydrates and protein. Many nutrients and phytochemicals present in fruits and vegetables, including potassium could independently or jointly reduce cardiovascular disease risk [48]. Potassium is a systemic electrolyte that helps to co-regulates ATP with sodium. A potassium-rich diet favorably affects acid-base metabolism which may decrease the risk of developing kidney stones and bone loss [49].

Calcium

Calcium is an essential mineral of human body, not only for building strong bones and teeth but also regulates intracellular events in body tissues. Ca plays an important role in muscle contraction, enzyme activities, blood clotting, nerve functions and in maintaining homeostasis [44, 46]. Milk and dairy products are the major sources of calcium in the diet, followed by cereals and cereal products. Insufficient Ca intake in the diet may lead to the occurrence of osteoporosis and bone fractures in adults, softening and deformation of the bones (rachitis) in children below two years of age [50].

Magnesium

Magnesium is essential in human nutrition because of its function as a cofactor for more than 300 essential enzymatic systems, its requirement for increased DNA synthesis, energy metabolism as well as glycolysis and has also been displayed to be indispensable for mitochondria to perform oxidative phosphorylation [51]. Magnesium also helps in protein synthesis, bone mineralization, muscle and nerve transmission. Deficiency of Mg has been associated with vascular disease and insulin resistance [36]. Approximately 50% half of total body Mg is present in the bones. The other half is present intracellularly in the cells of body tissues and organs. Only 1% of the total body Mg is found in blood [52]. It plays an important role in muscle function, nervous system and strong bones and in reducing the risk of developing cardiovascular disease [53].

I.3.2. Micro-elements

Iron

Iron is a mineral required for the formation of hemoglobin which carries oxygen from the lungs to the rest of the body cells. Iron, being the most abundant metals in human body, plays a vital role in cellular processes such as synthesis of DNA, RNA and proteins, electron transport, cell proliferation and differentiation, cellular respiration and regulation of gene expression [54]. Dietary sources of iron occur in two forms *viz*. heme iron and non-heme iron. Heme sources are derived from animal foods and plant tissues whereas non-heme Fe is derived from plant tissues only [55]. Some studies have suggested that excessive iron may lead to the formation of reactive radicals and cause cell damage, iron imbalance can contribute to the development of numerous iron disorders, neurodegenerative disorders and possibly some cancers [56]. Iron deficiency anemia is the most common nutritional disorder in the world. The main cause of nutritional anemia is not only due to inadequate intake of iron but also poor absorption of iron. In India, the prevalence of anemia is very high affecting almost 58% of pregnant women. Insufficient intake of iron from the diet is the leading cause of anemia that affects people of all ages in underdeveloped countries [57].

Manganese

Manganese functions as cofactors for a large variety of enzymes involved in hydrolysis, decarboxylation, phosphorylation and transamination. It promotes activities of transferases such as glycosyltransferase and of superoxide dismutase and glutamine synthetase [44]. Mn is associated with bone development and with amino acid, lipid, protein and carbohydrate metabolism. Mn is transported in the body by transferrin, macroglobulins and albumin [58]. Sources of dietary Mn include rice, whole grain, tea and nuts. Excess Mn has been considered as toxic; in brain it may cause a Parkinson-type syndrome [59].

Copper

Copper is an essential catalytic cofactor of proteins and enzymes (called cuproenzymes) which participates in fundamental mechanisms, such as energy generation, cellular metabolism, hematopoiesis, oxygen transportation and signal transduction [60]. The Cu-dependent enzyme, lysyl oxidase, for example, is vital for cross-linking collagen and elastin both of which are required for the formation of connective tissue. Ceruloplasmin, a Cu-dependent ferroxidase, facilitates transport from interstitial lumen and storage sites to the sites of erythropoiesis [61]. Cu is a component of cytochrome c oxidase that catalyzes the reduction of oxygen to water, the essential step in cellular respiration, and is a part of copper, zinc-superoxide dismutase (Cu, Zn-SOD) which scavenges superoxide free radicals. [44].

Zinc

Zn is required for the catalytic activity of about 200 enzymes and plays an important role in immune function, wound healing, DNA synthesis, protein synthesis and cell division [62]. Zinc is known to have antioxidant properties which works to slow down accelerated aging and helps in healing the injured tissues [63]. Like calcium, Zn also acts as intracellular second messenger in various biological systems [64]. In the brain, zinc accumulates in glutamatergic synaptic vesicles and can modulate brain excitability [65]. It was recommended that the average dietary intake of Zn is 9 mg/day for adult females and 12 mg/day for adult males by the Japanese Ministry of Health, Labour and Welfare [66]. Deficiency of Zn in childhood causes the retardation of physical development, dwarfism, learning disabilities and dysfunction of the immunological system. Moreover, Zn deficiency is associated with a risk for depression and stress [67].

Cobalt

Cobalt is an essential element of vitamin B12 (cyanocobalamin) that catalyzes reactions, such as the synthesis of methionine, the formation of methylmalonic acid in succinic acid and the metabolism of purines and folates [68]. However, excessive intake of this trace element may result in goiter and reduces thyroid activity. Exposure to cobalt has been associated with the development of congestive cardiomyopathy. In addition to its role in vitamin B12, cobalt is also a cofactor of enzymes which is involved in amino acid metabolism and DNA biosynthesis [69].

1.4 Vitamin C (Ascorbic Acid)

Vitamin C, also known as ascorbic acid, is a potent water-soluble antioxidant that plays a significant role in human physiology although the body cannot synthesize it and therefore must be introduced exogenously [70]. One of the important roles of vitamin C is to protect cellular components against free radical-induced damage. Vitamin C has the capability to scavenge free radicals in the aqueous phase of the cell and the circulatory system. In addition, vitamin C is most effective in regenerating the antioxidant form of vitamin E by reducing tocopheroxyl radicals, thereby indirectly protecting biological membranes and other hydrophobic compartments from free radical-induced damage. Coenzyme Q10, functions in its reduced form, can interact with vitamin C, and in this process the antioxidant form of coenzyme Q is regenerated [71]. Vitamin C, being a reducing agent and an electron donor, neutralize free radicals by donating its electron and is oxidized to dehydroascorbic acid. Dehydroascorbic acid may be reduced back to ascorbic acid for reuse or may be metabolized, further releasing more electrons [72]. Human diseases such as stroke, atherosclerosis and cancer are linked to excessive oxidative stress. Therefore, vitamin C supplementation has been advocated to reduce the risk of such diseases. Epidemiological studies have shown that diets rich in fruits and vegetables are effective in reducing the risk of stroke, atherosclerosis and cancer [73]. There is some evidence to suggest that vitamin C can regenerate vitamin E from its oxidized state to its reduced state. Vitamin C is widely distributed in plant cells and serves many functions in plants. For example, it serves as a major redox buffer [74], as a cofactor for several enzymes and as a major antioxidant [75]. Ascorbic acid also regulates cell division and growth as well as in signal transduction [74]. Fruit and vegetables are rich in dietary fiber, micronutrients (vitamins and minerals) and phytochemicals and the presence of such nutrients may affect the bioavailability of vitamin C [76]. Some fruit such as kiwifruit, contain large amounts of vitamin E and one animal study has showed that vitamin E is able to preserve vitamin C *in vivo* [77]. Synthetic and food-derived vitamin C is the most efficient enhancer of non-heme iron absorption [78].

1.5 Phytochemicals

Phytochemicals are naturally occurring chemical compounds produced by plants that have protective or disease preventive properties. They are non-nutritive bioactive compounds.

These phytochemicals are classified as primary metabolites such as carbohydrates, proteins and lipids and secondary metabolites which include alkaloids, steroids, flavonoids, terpenoids, tannins and many others [79]. They have biological properties such as antioxidant, antimicrobial, stimulation of the immune system, modulation of detoxification enzymes, modulation of hormone metabolism, decrease of platelet aggregation and anticancer property [80]. It is widely known that plants produce these chemicals to prohibit themselves from diseases and contribute to the plant's color, aroma and flavor, but recent researches demonstrated that many phytochemicals can also protect human against various diseases [81]. So far, about 10,000 individual phytochemicals have been identified in fruits, vegetables and grains, but a large percentage still remains unknown and need special attention to understand the potential mechanisms of action in the prevention and treatment of human health against chronic diseases [82]. Plant biomolecules have been reported to be alternatives to antibiotics resistance of human pathogens because of their proven therapeutic effectiveness and availability [83]. The uses of chemical compounds present in various plant species have different medicinal effects which have been shown to have scientific basis. The biomolecules help the body cell wall and DNA to reduce and neutralize reactive oxygen species such as hydroxyl (OH^-), superoxide ($O_2^{\bullet -}$), peroxyl ($RO_2^{\bullet}$), lipid peroxyl ($LOO^{\bullet}$), nitric oxide ($NO^{\bullet}$) generated during normal metabolic processes in human body [84].

Phenolic compounds are a large group of plant secondary metabolites and are important determinants in the sensory and nutritional quality of fruits, vegetables and other plants. Phenolic compounds possess an aromatic ring having at least one or more hydroxyl groups attached to a benzene ring and their structures may vary from that of a simple phenolic molecule to that of a complex high-molecular weight polymer [85]. These are hydroxylated derivatives of benzoic acid present in the form of glycosides and esters. The most abundant antioxidants in the diets of human are dietary polyphenols. It has been estimated that, more than 8000 dietary phenolics have been identified, and their distribution and accumulation profiles can be affected by both genetic and environmental factors [86]. Among more than 25,000 secondary metabolites that have been identified in plants, phenolic compounds have been exploited as scavengers and inhibitors due to their antioxidant, antibacterial, anti-inflammatory, anti-allergic, anti-tumor properties and anti-aging [87]. In particular, natural phenolic compounds have been reported to have excellent properties as food preservatives [88] and important properties for protection against a number of pathological disturbances such as atherosclerosis, cancer and brain dysfunction [89]. Moreover, polyphenols have many industrial applications, for example, they may be used as natural colourants for foods, pharmaceuticals or in the production of paper, paints, and cosmetic. There are several important classes of phenolic compounds (**Table I.3**). According to the basic skeleton, the structure of natural polyphenols ranges from simple phenolic molecules (volatile phenols) to highly polymerized substances such as condensed tannins [90].

Table I.3: Important classes of phenolic compounds in plants

Class	Examples
Simple phenols	Phenol, guaiacol
Benzoquinones	2,6- Dimethoxybenzoquinone
Hydroxybenzoic acids	Gallic, p-hydroxybenzoic, salicylic
Acetophenones	3-Acetyl-6-ethoxybenzaldehyde
Phenylacetic acids	p-Hydroxyphenylacetic
Hydroxycinnamic acids	Caffeic, ferulic, p-coumaric
Phenypropenes	Myristicin
Coumarins	Aesculetin
Isocoumarins	Bergenon
Chromones	Eugenin
Naphthoquinones	Juglone
Xanthones	Mangiferin
Stilbenes	Resveratrol
Anthraquinoids	Emodin
Flavonoids	Quercetin, catechin
Isoflavonoids	Genistein
Lignans	Pinoresinol
Neolignans	Eusiderin
Biflavonoids	Amentoflavone
Lignins	
Catechol melanins	
Condensed tannins	

Source: Waterman and Mole [90].

I.6 Antioxidants

Fruits are important dietary sources of various antioxidant phyto-compounds for humans. Wild edible fruits contain significant amount of nutrients and bioactive compounds more or less similar to cultivated species. Wild edible fruits can be rich sources of various vitamins, minerals, fibers and polyphenol which provide health benefits in addition to their nutritional value. Epidemiological studies have shown that increased consumption of fruit and vegetables can reduces the risk of several diseases like diabetes, cancer, coronary heart disease, neurodegenerative ailment and other chronic diseases [91]. Consumption of fruits can provide protection against free radicals that damage lipids, proteins, and nucleic acids. Polyphenols, carotenoids (pro-vitamin A), vitamins C and E present in fruits have antioxidant potentials and can scavenge free radicals and play a pivotal role in decreasing the development of many diseases. The antioxidant activity of polyphenols is mainly because of their redox properties which can play a significant role in neutralizing free radicals, singlet and triplet oxygen, or decomposing peroxides [92].

In recent decades, natural plant materials have been identified and documented as promising sources of valuable therapeutic properties. Available data from scientific reports indicate that natural plant products which possess antioxidant activity have beneficial impact on human health [93]. Phenolic compounds in plants are naturally occurring antioxidants because of their capability to scavenge free radicals originating from different reactive oxygen species (ROS) and reactive nitrogen species (RNS), such as hydroxyl radical ($HO^{\bullet}$), superoxide anion ($O_2^{\bullet-}$), peroxyl radical ($ROO^{\bullet}$), hydrogen peroxide (H_2O_2), nitric oxide ($NO^{\bullet}$), hypochlorite ion ($ClO^{\bullet-}$), singlet oxygen ($^1O_2$) and peroxy nitrite ($ONOO^{\bullet-}$) [94, 95]. For most living organisms, free radicals and reactive oxygen species are regularly produced through frequent physiological and biochemical processes as byproducts of normal cellular metabolism in aerobic organisms [96]. Being highly unstable and reactive, they undergo chemical reactions either to grab or donate electrons, thereby possessing ability to oxidative damage of essential biomolecules such as lipids, proteins and DNA in the form of tissue injury, gene mutation and cell death that can initiate the development and progression of number of diseases like congestive heart failure, atherosclerosis, diabetes mellitus, cancer, and neurodegenerative diseases etc. [97]. Their harmful effect can however be blocked by antioxidant substances which continuously and proportionally neutralizes free radicals by scavenging. Plants produce wide array of secondary metabolites such as vitamins, terpenoids, phenolic compounds (phenolic acids, flavonoids, coumarins and quinines), nitrogen compounds (alkaloids and amines), and other secondary metabolites that have been proved for antioxidant activities [98].

Current research has revealed that antioxidants are most useful in protecting cells from ROS and retard the progress of many health disorder as well as lipid peroxidation [99]. Therefore, these natural plant antioxidants can be considered as a type of preventive medicine. Recent reports revealed that there is an inverse relationship between the incidence of human disease and dietary intake of antioxidant rich food [100]. Free radicals due to different exogenous factors such as environmental pollutants, chemical exposure, radiation, toxins, physical stress etc. cause depletion of immune system, change in gene expression and induce abnormal proteins. The process of oxidation is one of the most important route for generating free radicals in food, drugs and living systems. The enzymes catalase and hydroperoxidase enzymes convert hydrogen peroxide and hydroperoxides to non-radical forms and function as natural antioxidants in human system. Due to depletion of immune system natural antioxidants in different maladies, the external aid of antioxidant in the form of food supplements as free radical scavengers may be necessary [101]. According to Halliwell *et al.* [95] free radicals have been associated with more than one hundred human disorders. Currently available synthetic antioxidants such as butylated hydroxy toluene, butylated hydroxy anisole, tertiary butylated hydroquinone and gallic acid esters have been widely used as antioxidants in food industry [102]. However, they have been suspected to cause liver damage and carcinogenesis. Hence, their application as food additives in dietary items is restricted due to scientific reports published on their involvement in number of diseases [103]. Recently there has been an upsurge of interest in finding therapeutic potentials of medicinal plants as antioxidants to replace synthetic ones. Besides well-known traditionally used natural antioxidants from fruits, vegetables, tea, wine and spices, some natural antioxidants e.g. sage and rosemary are already commercially exploited either as nutritional supplements or antioxidant additives [104]. Natural antioxidant substances are considered to be safe since they occur in plant foods, and are found as more desirable than their synthetic counterparts. Natural antioxidants occur in all parts of the higher plants (fruit, leaves, stem, bark, roots, flower, pollen, seeds and pods) [105]. To meet this challenge, intensive research activities are being carried out currently on various plant species for novel antioxidants. Indeed, several studies have reported that the antioxidant activity of plant species might be due to their phenolic compounds [106]. It has been determined that polyphenols, such as flavonoids, proanthocyanidins and hydroxycinnamic acids, act as more potent antioxidants than ascorbic acids. Phenolic antioxidants have been recognized as an important class of food ingredients and are currently used as food additives in order to provide additional health benefits [94]. Flavonoids and phenolic compounds in plants are most important groups of secondary metabolites which is considered as good sources of naturally occurring antioxidants in human diet. These compounds have a radical scavenging capability and had been proven to inhibit tumorigenesis and metastasis. They are known to have antibacterial, antifungal, anti-aging and anti-inflammatory activities [107]. In recent years, phenolic compounds have received considerable attention because of their valuable therapeutic properties [108].

I.7 Antimicrobials

During the last few decades, the incidence of microbial infectious diseases and their complications are continuously increasing throughout the world mainly due to microbial drug resistance among the various strains of microorganisms [109]. Antibiotic resistance has become one of the biggest threats to human health since late 20^{th} century [110]. The need for new antimicrobial agents, which could effectively act against resistant microbes, has tremendously increased. Traditional approaches to find new antimicrobial drugs have become less and less effective due to the rapid emergence of drug resistant-bacteria. Consequently, it is very important to investigate newer drugs with lesser resistance. Plant materials have been investigated to be one of the most promising sources [111]. Plant derived antimicrobial compounds are also considered relatively safer compared to synthetic compounds because of their natural origin. It is well known that about 50% of all the drugs in modern therapeutics are of natural products and their derivatives. Plant-derived antimicrobial compounds could have other target sites than traditional antimicrobials and subsequently having different possible mechanisms of action against microbes [112].

Plants have virtually unlimited capacity to produce aromatic secondary metabolites, most of which are phenols or their oxygen substituted derivatives [113]. Important subclasses in this group of compounds which have been found to have antimicrobial activity include phenols, phenolic acids, quinones, flavones, flavonoids, flavonols, tannins and coumarins. These groups of compounds show antimicrobial effect and serve as plant defense agents against pathogenic microorganisms. The site and number of hydroxyl groups present in aromatic ring are probably responsible for phenolic toxicity to microorganisms [114]. Flavones, flavonoids and flavonols are known to be synthesized by plants in response to microbial infections and are found to be effective *in vitro* as antimicrobial substances against a wide range of microorganisms [115]. Tannins are water soluble polyphenols that are commonly available in higher herbaceous and woody plants [114]. Tannins possess astringent properties and have been reported to be bacteriostatic or bactericidal against *Staphylococcus aureus* [116]. Coumarins are compounds that belong to a class of phenolic substances and are made of fused benzene and α-pyrone rings. As a group, coumarins have been shown to stimulate macrophages which could have an indirect negative effect on infections [110]. There are several mechanisms of plant metabolites' antimicrobial action. Phytochemicals can act by impairing cellular metabolism (cinnamaldehyde) or disrupting microbial membranes (carvacrol, eugenol, thymol etc.). They may control biofilm formation also (trans-cinnamaldehyde, thymol, carvacrol, geraniol, etc.). Plant-derived antimicrobials can inhibit bacterial capsule production (salicylic acid and its derivatives). Plant compounds can also attenuate bacterial virulence by controlling quorum-sensing. Another mechanism of plant metabolites' antimicrobial action is to reduce the production of microbial toxin (dihydroisosteviol, RG-tannin, etc.) [111]. Plant secondary metabolites can also act as resistance-modifying agents (RMAs). Nowadays RMAs are regarded as one of the most prospective ways to combat bacterial resistance. Several studies have already showed that plant compounds can enhance therapeutic effect of antibiotics acting as RMAs (nerolidol, apritone, bisabolol etc.) [112].

The number of higher plant species are currently estimated to be around 250–500 thousands [110]. However, only a small part of them were investigated for antimicrobial activity. People started to use plant materials to treat infectious diseases since ancient times even without any knowledge on their causative agents [111]. In more than 80% of developed countries, plants have been used as traditional medicine as they are the good source of therapeutic agents. Therefore, plants are investigated for better understanding of their properties, safety and efficacy. Many plants have been used for their antimicrobial traits, which are chiefly due to the synthesis in the secondary metabolism of the plant [117] and their inhibitory effect against the growth of human pathogenic microorganisms. Keeping this in view, efforts are (currently) underway to search for economic and safe phytochemicals which could be used for disease control. Despite the existence of potent antibiotic and antifungal agents, resistant microbial strains are continuously appearing, suggesting the need for a permanent search and the development of new drugs [118].

I.8 Amino acid

Amino acids are defined as organic substances containing both basic amino group ($-NH_2$) and acidic carboxyl group ($-COOH$). All amino acid except for the simplest amino acid, glycine have an asymmetric carbon atom and exhibit optical activity. The absolute configuration of amino acid (D- or L- isomers) is defined with reference to the enantiomers of glyceraldehyde. All amino acid except for proline found in protein have a primary amino group and a carboxyl group linked to the α-carbon atom (hence the name α-amino acid). In β-amino acid (e.g. taurine and β-alanine), an amino group is attached to the β-carbon atom. Post-translationally modified amino acid occur in some proteins [119]. Amino acids have remarkably different biochemical properties and functions because of variations in their side chains [120].

Adequate dietary provision of amino acids is essential for the health, growth, development and survival of humans and animals [121]. Traditionally, amino acids have been classified as nutritionally essential or non-essential for humans and animals based on dietary needs for nitrogen balance or growth [122]. The essential amino acid are histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The non-essential amino acids are alanine, arginine, asparagine, aspartate, cysteine, glutamate, glutamine, glycine, proline, serine, taurine, and tyrosine [123, 124]. The essential amino acid requirements for adults based on FAO/WHO/UNU 2007 [125] are presented in **Table I.4**. Nutritionally essential are those amino acids whose carbon skeletons cannot be synthesized in animal cells or those amino acid that usually are insufficiently synthesized by the animal organism relative to its needs for maintenance, growth, development, and health and therefore must be provided in the diet to meet the requirements [123]. In contrast, nutritionally non-essential amino acids are synthesized sufficiently in the body to meet the requirements for maintenance, growth, development and health and, therefore, need not be provided in the diet [126].

Table I.4: Essential amino acid requirements for adult (FAO/WHO/UNU 2007) [125]

Amino acid	**mg/kg/day**	**mg/g protein**
Histidine	10	15
Isoleucine	20	30
Leucine	39	59
Lysine	30	45
Methionine	10	16
Cysteine	4	6
Methionine + Cysteine	15	22
Threonine	15	23
Phenylalanine + Tyrosine	25	38
Tryptophan	4	6
Valine	26	39
Total essential amino acid	184	277

Although essential amino acid and non-essential amino acid had been described for over a century, there are no compelling scientific evidence to substantiate the assumption that non-essential amino acid are synthesized sufficiently in humans and animals to meet the needs for maximal growth and optimal health [124]. However, growing evidence from cell culture and animal studies shows that non-essential amino acid (e.g. glutamine, glutamate, and arginine) play important roles in regulating gene expression, cell signaling pathways, digestion and absorption of dietary nutrients, DNA and protein synthesis, proteolysis, metabolism of glucose and lipids, endocrine status, men and women fertility, acid–base balance, anti-oxidative responses, detoxification of xenobiotics and endogenous metabolites, neurotransmission, and immunity [127].

Glutamine has numerous functions including roles in regulating intracellular protein synthesis, glutathione production, cell proliferation and maintenance of acid-base balance in the kidney [121]. Glycine is the main component of collagen and elastin which are the most abundant proteins in the body. Glycine acts as precursor for several important metabolites of low molecular weight, such as glutathione, porphyrins, purines, heme, and creatine. Glycine also acts as an inhibitory neurotransmitter in the central nervous system and has many roles such as antioxidant, immunomodulatory, anti-inflammatory, and cytoprotective in both peripheral and nervous tissues [128]. Arginine is considered as semi-essential amino acid and has protective effects against oxidative stress. As the precursor of nitric oxide synthesis, arginine is reported to be therapeutic in the healing of wounds and has potent anti-inflammatory properties as a mediator of autoimmune diseases and has several immunomodulatory effects [129]. Leucine is a dietary amino acid that can stimulate synthesis of muscle protein and has important therapeutic role in stress conditions like trauma, burns, and sepsis [130]. The WHO recommended daily intake of leucine as 39 mg/kg/day [131]. Methionine, a sulfur amino acid is a universal methyl donor for more than hundred reactions [132]. Excessive uptake of methionine might lead to hyperhomocysteinemia [133]. Methionine is used for treating liver disorders, improving wound healing and treating depression, alcoholism, drug withdrawal, asthma, and allergies, copper poisoning, radiation side effects, schizophrenia and Parkinson’s disease [134]. Tryptophan serves as precursor for the synthesis of neurotransmitters serotonin, an important neuromediator associated to mood, stress response, sleep and appetite regulation. Tryptophan is also the precursor of hormone melatonin, tryptamine, and kynurenine and plays an important role in the functioning of neurotransmitters like dopamine and nor-dopamine [135]. Histidine is the most active and versatile member that plays multiple roles in protein interaction and is also a precursor of histamine. It is needed for the maintenance of the myelin sheaths, growth and repair of tissue and aids in removing heavy metals from the body [136]. Lysine is an essential amino acid which is important for carnitine synthesis. It is also required for optimal growth and its deficiency leads to immunodeficiency [137]. The importance of lysine is because of its involvement in the collagen construction. The daily intake of lysine is about 40–180 mg/kg of body weight; however, there have been reports of up to 300–400 mg intake [138]. Glutamic acid is a non-essential amino acid being synthesized from substances like alpha-ketoglutarate and the other amino acids such as ornithine, arginine, proline and glutamine. It also stimulates neuron activity and plays an important role in learning and memorizing [139]. Aspartic acid, a dispensable acidic amino acid, is synthesized from glutamate in the liver by enzymes using vitamin B6 and is formed from oxaloacetate by transamination. It is a major excitatory neurotransmitter like glutamic acid [140]. Branched chain amino acid namely valine, leucine and isoleucine have been found to promote muscle protein synthesis and reduce protein catabolism. Therefore, branched chain amino acid enriched nutrition has been recommended as potentially therapeutic for critically ill patients [130]. Alanine is the major gluconeogenic substrate in all mammals, and glucose is essential for the functions of red blood cells and brain [141]. Phenylalanine is essential for the synthesis of a pigment known as melanin that contributes to skin colour, eye and hair [142]. Phenylalanine is the precursor for the synthesis of neurotransmitters such as dopamine, epinephrine, norepinephrine and thyroid hormones. Similarly, serine is the precursor of cysteine, glycine and tryptophan and plays a significant roles in cell signaling. Serine is also being utilized for the treatment of schizophrenia. The essential amino acid threonine is important in treating some types of nervous system disorders including multiple sclerosis, spinal spasticity, familial spastic paraparesis and amyotrophic lateral sclerosis [143].

I.9 Anti-nutritional factors

Wild edible fruits are good source of vitamins, fiber and minerals which provide essential nutrients for the human health [144]. Despite their nutritional and health benefits, there is dearth information about the anti-nutrient contents of these wild fruits. It is observed that the nutritional contents of these wild fruits have higher nutritional values compared to cultivated fruits [2]. However, some of these fruits are also known to contain anti-nutritional factors that interfere with the metabolic process of the body which in most cases predispose negatively on growth and bioavailability of nutrients [145]. Some of the common examples of anti-nutritional factors are such as lectins, trypsin (protease) inhibitors, non-protein amino acids, alkaloids, cyanogenic glycosides, erucic acid or phytates [146].

Anti-nutritional factors or anti-nutrients are those substances generated naturally in food stuffs by the normal metabolism of species and by different mechanism such as inactivation of some nutrients, diminution of digestive process or metabolic utilization of feed/food which exert effects contrary to optimum nutrition [147]. In some cases, anti-nutrients can simply be toxic or may cause adverse physiological effects such as flatulence. However, recent studies have revealed that some anti-nutrients may exert beneficial effects when ingested in small quantities and may even help in the prevention of certain illnesses including cancer and coronary disease. As a result, they are often known as non-nutritional compounds, since they have no direct nutritional value but are not always harmful [148]. Aberoumand and Deokule [4] also reported that these anti-nutritional factors could help to prevent and treat several important diseases like the anti- carcinogenic activity of the phytic acid that has been demonstrated in several *in vitro* and *in vivo* assays.

Currently, the consumption of fruits and vegetables are widely recommended for their health benefits because of the presence of nutritive and non-nutritive chemicals which protect the humans from diseases related to oxidative stress. Although the wild fruits offer nutritious dietary supplements, more intake of such fruits is hazardous to our body, therefore before consumption it must be checked whether it contains any anti-nutritional factors. The anti-nutritional factors such as tannins and trypsin inhibitors inhibit absorption of iron and zinc, protein digestion and growth [149]. Pahnwar [150] revealed the presence of anti-nutrients such as oxalates, phytates, oligosaccharides, aflatoxin and hydrogen cyanide in peanuts and their effects on health. Natural antioxidants from edible plants offer an alternative source of dietary components to promote healthy life. For example, α-amylase and α-glucosidase inhibitors are considered an effective measure to regulate type II diabetes by controlling glucose uptake [151].

Alkaloids are synthesized by plants and generally present as salts of plant acids such as malic, oxalic, tartaric or citric acid [152]. Alkaloids are considered to be anti-nutrients because uptake of high dose of alkaloids may cause gastrointestinal and neurological disorders. The glycoalkaloids, chaconine and solanine present in potato and *Solanum* spp. have been found toxic to fungi and humans. Some plant alkaloids are also reported to cause infertility [153].

Tannins are amorphous, astringent substances and most widely occurring anti-nutritional factors found in plants. They are water soluble phenolic compounds with high molecular weight ranging from 500 to over 3,000. Tannins are chemically divided into two broad groups namely, hydrolysable and condensed tannins [154]. Tannins have been reported to inhibit the activities of digestive enzymes and thereby lower digestibility of most nutrients, especially carbohydrates and protein [155].

Saponins are structurally diverse molecules and contain a steroidal or triterpenoid aglycone to which one or more sugar chains are attached. They are generally known as non-volatile, surface active which are found widely in the plant kingdom. Saponins have been reported to possess hypocholesterolemic, immunostimulatory, and anti-carcinogenic properties [156]. In addition, they also reduces the risk of heart disease, control plasma cholesterol, prevent peptic ulcer and osteoporosis, in consumption saponin rich diet [157].

Cyanogenic glycosides are chemical compounds that can be hydrolysed to release hydrogen cyanide by enzymes that are found in the cytosol [158]. The toxicity of a cyanogenic plant depends on the release of hydrogen cyanide. Cyanide toxicity can occur in animal including humans at a range of 0.5 and 3.5 mg HCN per kg of body weight [159]. There are approximately 25 known cyanogenic glycosides and are naturally present in seeds of apples, apricots, cherries, peaches, plums, quinces [160]. Hydrogen cyanide can cause dysfunction of the central nervous system, cardiac arrest and respiratory failure [161].

Oxalate is a common constituent of many plants species including some crop plants which accumulate high levels of this dicarboxylic acid anion (oxalate) [162]. Oxalate exists as soluble and insoluble forms in plants. Oxalic acid binds to calcium and is generally found in a variety of fruits, vegetables, legumes, nuts and grains. It has been reported that ingestion of insoluble oxalates causes irritation and swelling of mouth and throat [163].

Phytic acid also known as inositol hexakisphosphate is the primary storage form of phosphorus in plant seeds and occurs naturally in grains, nuts, legumes, and oil seeds [164]. Many essential elements like iron, zinc, calcium and phosphorous are combined by phytic acid to form insoluble phytate salt which are not absorbed by the body and thus reducing the bioavailability of these elements [165]. It has been reported that phytate also binds proteins and starch forming insoluble complexes thereby reducing their bioavailability and digestion in humans [166].

Protease inhibitors are substances that have the ability to inhibit the activity of proteolytic enzymes within the gastrointestinal tract of animals. Protease inhibitors are found abundantly in raw cereals and legumes, particularly soybeans. Because of their protein nature, protease inhibitors can be easily denatured and inactivated by heat processing although about 5-20% of the activity may still remain in commercial soya products. The activities of protease inhibitors have been associated with growth inhibition and pancreatic hypertrophy [167]. Trypsin inhibitor and chymotrypsin inhibitor are protease inhibitors that occur in raw legume seeds. Trypsin inhibitors that inhibit the biological activity of trypsin and chymotrypsin in the gut, thereby preventing digestion of protein, are available in many plant species, particularly in grain legumes [168].

Amylase inhibitors, also known as starch blockers prevent the absorption of starch into the body by blocking the hydrolysis of 1, 4-glycosidic linkages of starch and other oligosaccharides into maltose, maltriose and other simple sugars [169]. Starches are complex carbohydrates that need to be broken down first by the digestive enzymes amylase and other secondary enzymes in order to be absorbed. Alpha amylase inhibitor plays a major role in the management of postprandial hyperglycemia by decreasing glucose release from starch [170]. It inhibits the activity of alpha amylase which leads to a reduction of hydrolysis of starch to maltose and consequentially lower postprandial hyperglycemia [171].

I.10 Review of literature

There are a number of works on the wild edible fruits 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 fruits are highlighted in this chapter of the thesis.

Saka and Msonthi [5] studied the chemical composition of sixteen indigenous fruits consumed in Malawi and reported that *Trichilia emetica* contained the highest level of protein (17.0%). All the fruits were found to be important sources of Fe such as *Flacourita indica* (734 µg/g) and *Syzigium guineense* (758 µg/g) being the best sources. The fruits *Adansonia digitata* (1156 µg/g), *Bauhinia thonningii* (983 µg/g) and *Vitex doniana* (926 µg/g) are found excellent sources of Ca which could satisfactorily meet man's daily requirement.

Indigenous fruits were collected at two conservation areas in Kanchanaburi province, Thailand and their nutrient contents and bioactive compounds were determined by Judprasong *et al.* [172]. The results showed that *Phyllanthus emblica* L. had the highest concentration of vitamin C (575 ± 452 mg/100 g) and total phenolics (3703 ± 1244 mg GAE/100 g). *Antidesma velutinosum* Blume exhibited higher levels of most nutrients, dietary fibre (15.6 ± 5.9 g/100 g), phytosterols (22.1 ± 3.9 mg/100 g) and carotenoids (335 ± 98 µg/100 g) compared to other fruits. They reported that consumption of a variety of such fruits can potentially contribute to health improvement as these Thai indigenous fruits are good sources of nutrients and bioactive compounds.

Hoe and Siong [173] showed nutrient composition of 16 fruit species of indigenous origin in Sarawak, Malaysia. Four fruit species *viz*. *Durio kutejensis*, *Durio graveolens*, *Dacryodes rostrata* and *Canarium odontophyllum* were reported to be very nutritious with high values for energy, protein and potassium. All the fruits analyzed had low content of vitamin C except *Durio kutejensis* (15.9 mg/100 g).

Magaia *et al*. [174] examined traditional utilization and proximate composition of five edible wild fruits in Mozambique and they are *Adansonia digitata*, *Landolphia kirkii*, *Sclerocarya birrea*, *Salacia kraussii* and *Vangueria infausta*. It was reported that the kernels of *A. digitata* contained much higher protein (39.2%) and fat (38.0%). They said that these edible fruits play an important role in the diet of rural people and are very popular in Mozambique.

Salih and Yahia [175] investigated fruit pulps of doum (*Hyphaene thebaica* L. Mart.), baobab (*Adansonia digitata* L.), tamarind (*Tamarindus indica* L.) and jujube (*Ziziphus spina-christi* L. Willd.) from Nuba Mountains, Sudan for their proximate composition, mineral contents, total soluble phenols, total carotenoids and total antioxidant capacity. Results showed that *A. digitata* and *H. thebaica* had the highest total carotenoid content (16 mg/kg) and total phenolic content (45.08 ± 1.02 mg gallic acid equivalent/g) respectively. It was also reported that the mineral content of the fruits were high (14–45 mg/g) and antioxidant capacity varied from 120–425 µmol trolox equivalent/g dry weight.

Osman [176] examined nutrient contents of baobab (*Adansonia digitata*) seed and fruit pulp. The pulp is used as beverage ingredients and the baobab seed showed a rich energy (363.8 ± 9.7 kcal/100 g) and protein content (18.4 ± 0.5%). The fatty acid profile showed major unsaturated fatty acids such as oleic (35.8%) and linoleic acid (30.7%) whereas palmitic acid (24.2%) was reported to be the major saturated fatty acid.

Fruits of *Boscia senegalensis* (mukheit) and *Dobera roxburghi* (maikah) collected from Northern provinces of Kordofan were evaluated for their nutritional value and chemical composition [177]. Both the fruits have a good nutritional value and are compared favorably with starch and soluble carbohydrate content of the staple cereals and sorghum. The protein of sweetened maikah had a chemical score of 85 which is far superior to that of the local cereals. Maikah had also an exceptionally high content of calcium (2.9 g/kg) and zinc (45 mg/kg).

Blackthorn (*Prunus spinosa* L.) reported by Marakoglu *et al*. [178] is popularly known as ‘sloes’ and grows wildly in various regions of Turkey. Sloes are blueish black colour, 10-15 mm with green astringent flesh and have laxative properties. Study results showed that blackthorn fruits contained high amounts of potassium (18706.98 mg/kg), sulphur (500025.97 mg/kg) and calcium (1524.22 mg/kg).

Satpathy *et al*. [179] investigated the nutraceutical and therapeutic potential of *Spondias pinnata* fruit from the eastern region of India. The study revealed a rich source of energy (348 kcal/100 g), minerals, nutraceutical and natural antioxidant such as total phenolics content (210 ± 1.89 mg gallic acid equivalent/100 mg) and flavonoids (28.0 ± 0.91 mg catechin equivalent/100 mg).

Ayessou [180] investigated the nutrient composition of wild fruit *Dialium guineense* from the sub-Guinean forests of Senegal. Results showed that the fruit had high content of glucose and fructose (90.8% of total soluble sugars). *D. guineense* fruit appeared to be a potentially good source of sugars and micronutrients including Mg (0.1 g/100 g), Fe (4.8–8.4 mg/100 g) and Cu (0.7 mg/100 g) and can contribute towards meeting the recommended daily allowances to combat malnutrition.

Murugkar and Subbulakshmi [181] studied fourteen wild edible plants consumed by the Khasi tribe of Meghalaya for their nutrient contents in terms of macronutrients, vitamins and minerals. The study revealed that *Coix lachryma* and *Solanum indicum* had the highest level of protein (13.3 g %) and vitamin C (826.4 mg %) respectively. *Castanopsis indica* showed good amounts of calcium (1540 mg %) whereas *Kaempfaria galanga* contained good amounts of iron (69.91 mg %) and zinc (8.4 mg %).

Seal [182] studied different nutritional potential of wild edible plants of Meghalaya, India and found that nutritional values of these edible plants were richer compared to commercial vegetables and could be used for nutritional purpose. The study revealed that *E. pyriformis* contained the highest level of protein (231.8 ± 0.50 g/kg) and nutritive value (3827.03 ± 5.45 kcal/kg). *Diplazium esculentum* showed the highest quantity of potassium (43730 ± 110.0 mg/kg) among the macronutrients estimated in various wild edible plants.

Sadia *et al*. [183] evaluated nutrient and mineral composition of edible wild fruits and mulberry fruits and revealed that both the fruits are rich sources of protein, carbohydrate, fibers and vitamins with higher energy values observed in *Morus laviegata* (367.74 ± 0.35 kcal/100 g dry weight). Results also showed that sufficient essential micronutrients such as K, P, Mg, Ca and Fe were found in all the fruits. The highest levels of Na (1.92 ± 0.11 mg/g) and Mg (6.92 ± 0.37 mg/g) were found in *Ficus palmata* whereas N (0.24 ± 0.07 mg/g) and Fe (1.43 ± 0.42 mg/g) were found in *Morus laviegata*.

Maikhuri *et al*. [184] studied the nutritional and energy value of an underutilized wild edible fruit *Viburnum mullaha*. Results showed that the fruit contained high amount of vitamin C (122.27 mg/g) and energy value of 284.4 kcal/100 g. The various micro and macro minerals were also determined and confirmed that the fruit berries of *Viburnum mullaha* showed highest level of potassium (9.01 ± 0.018 mg/g) and could be a potential source to combat the hidden hunger of micro and macro nutrient deficiencies. Analysis of manganese, iron, copper, zinc and magnesium confirmed that fruit berries of *Viburnum mullaha* can be utilized for developing various edible products.

Leterme *et al*. [185] determined mineral contents of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia. It was reported that the foods were generally high in K that ranged from 1.782 mg/100 g to 36 mg/100 g edible portion and low in sodium (<45 mg/100 g edible portion).

Arunachalam *et al*. [186] analyzed the nutritional, chemical composition and antioxidant activity of *Ficus amplissima* fruit. It was reported that the fruits contained appreciable amounts of calcium (25.97 mg/100 g), sodium (13.5 mg/100 g), phosphorus (37.0 mg/100 g), iron (2.60 mg/100 g) and potassium (160.42 mg/100 g). Results also showed that the acetone extract of the fruit exhibited higher scavenging activity including $ABTS^{\bullet+}$ (6587.96 µmol trolox equivalent/g dry extract), phosphomolybdenum (277.15 mg ascorbic acid equivalent/g dry extract), FRAP (864.44 mM/g), superoxide (50.81%), hydrogen peroxide (62%) and hydroxyl activity (49.9%). The study suggested that fruits may be used as a natural dietary food supplement, chewed for mouth ulcers and also be used to cure the mentally deranged.

Calisir *et al*. [187] estimated mineral contents of wild plum (*Prunus* spp.) fruits by an inductively coupled plasma atomic emission spectrometer (ICP-AES) and found that all materials contained high amounts of Ca (920.82 mg/kg), K (9879.57 mg/kg), Mg (916.68 mg/kg), S (122.69 mg/kg), P (659.15 mg/kg), Fe (30.1 mg/kg) and Na (40.46 mg/kg).

Olayiwola *et al*. [188] analyzed phytonutrients, mineral composition and antioxidant activity of some wild fruits. It was reported that *Spondias mombin* fruit contained the highest level of vitamin C (204.86 mg/100 g) and total phenolics (398.23 ± 0.00 mg/100 g) whereas *Chrysophyllum albidum* showed the highest total carotenoid content (1380.17 µg/100 g). It was also reported that high potassium and low sodium content of wild fruits (except *Spondias* *mombin*) can be recommended as a part of hypertensive diet and people suffering from severe acute malnutrition.

Valvi and Rathod [189] investigated the mineral compositions of 8 wild edible fruits and high potassium contents were reported in all the fruits. *Ficus racemosa* fruit was reported to contain the highest amount of sodium (259.6 ± 1.5 mg/100 g), calcium (928.4 ± 0.41 mg/100 g) and potassium (1922 ± 2 mg/100 g). *Grewia tiliifolia* fruit was found rich in magnesium (402.2 ± 0.15 mg/100 g) and potassium (1302 ± 2 mg/100 g) whereas iron content was found more in *Meyna laxiflora* (35.55 ± 0.47 mg/100 g). *Elaeagnus conferta* fruit was found rich in zinc (5.51 ± 0.01 mg/100 g) while *Flacourtia indica* fruit was reported to contain rich in copper (7.6 ± 0.06 mg/100 g) and manganese (10.37 ± 0.49 mg/100 g).

Renna *et al*. [190] determined 13 elements *viz*. Na, K, Ca, Mg, Fe, Mn, Cu, Zn, Cr, Co, Cd, Ni and Pb in 11 different wild edible plants by inductively coupled plasma optical emission spectroscopy (ICP-OES). It was reported that *Borago officinalis* was good sources of Mn (155.92 mg/kg) and *Papaver rhoeas* was good sources of Fe (1732.2 mg/kg). *Portulaca oleracea* was reported to be a good source of Mg (12.28 mg/g).

Saklani *et al*. [191] studied the nutritional profile, antimicrobial and antioxidant activities of wild edible fruit of Himalaya (*Berberis asiatica*). The fruit was found to be a good source of essential nutrients including minerals such as calcium, magnesium, potassium and phosphorus which were 1.0, 8.4, 1.98 and 0.24 mg/100 g respectively. This study showed that the fruits contained higher levels of protein, fat, fibre and minerals as compared to the cultivated fruits. Also, the total phenolics and flavonoids contents were reported to be 670 ± 0.12 mg/100 g and 190.40 ± 0.52 mg/100 g respectively. The ethanolic fruit extracts showed the highest antimicrobial activity against *Streptococcus pyogenes* (15 ± 1 mm).

Llorent-Martínez *et al*. [192] determined the inorganic composition of six non-commercial wild berries and reported that the analyzed berries had low concentrations of Co, Mo, Ni and Cu, but reported to be rich sources of Ca, K, P, Na and Mg. Moreover, only very low concentrations of toxic elements were observed ensuring the absence of human health risks. This analysis revealed that *Rubus grandifolius* and *Sambucus lanceolata* would provide the highest contribution to the diet in terms of inorganic nutrients.

Glew *et al*. [193] investigated 16 minerals (Al, Ba, Cu, Ca, Fe, Co, K, Mg, Li, Mn, Ni, Na, P, Ti, Sr and Zn) in *Mespilus germanica* fruit, and showed their richness in potassium (7370 µg/g), magnesium (661 µg/g), phosphorus (1080 µg/g), calcium (1780 µg/g) and sodium (183 µg/g). They reported that the ripe fruit is an important source of nutritionally needed minerals such as Ca, K, Cu, Mg, Fe, Mn, Na and Zn for human populations in Southern Europe, Iran and Turkey.

Barreca *et al*. [194] assessed the methanol, ethanol and dimethyl formamide extracts of wild cherimoya fruits pulp (*Annona cherimola*) for its antioxidant capacities. All the three extracts exhibited strong free radical capturing and antioxidant activities. Among them, the ethanol extract showed the strongest anti-lipid peroxidation activity and the dimethyl formamide extract showed the highest DPPH (69%), ABTS (37.63 ± 2.62 µM trolox equivalent) and FRAP (2.75 ± 0.081 µM TE) activities.

The antioxidant activity of methanol extract of wild fruit *Lycium ruthenicum*, a functional food which has been used in traditional Chinese medicine, was evaluated by Zheng *et al*. [195]. The methanol extract showed potent antioxidant activity in ABTS (671.77 ± 137.01 mg/100 g), FRAP (811.96 ± 58.58 mg/100 g) and DPPH (1059.1 ± 72.08 mg/100 g) assays.

Rawat *et al*. [196] evaluated crude extract of *Myrica esculenta* fruit for its antioxidant properties. Results revealed that the extracts exhibited considerable antioxidant potential in DPPH (2.55 mM ascorbic acid equivalent/100 g), ABTS (1.84 mM AAE/100 g) and FRAP (2.97 mM AAE/100 g) assays and also showed significant positive correlation with total phenolic content and total flavonoids content.

Mezadri *et al*. [197] evaluated the antioxidant activity of hydrophilic extracts of *Malpighia emarginata* pulps and juices by 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2´-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) and oxygen radical absorbance capacity (ORAC) methods. Results showed that the DPPH, ABTS and ORAC values varied from 3.83–11.30 mM, 3.69–12.57 mM and 3.46–8.54 mM trolox equivalent (mM TE) respectively, for 100 g of fruit or 100 mL of juice. These values were found higher than those reported for other fruit juices in the literature such as apple, strawberry and grape. In addition, phenolic acids exhibited the highest antioxidant activity indicating that phenolic acids are the main contributor to the antioxidant property of wild acerola fruits.

Esfahlan and Jamei [198] evaluated biological activity of the fruits of 10 wild almonds (*Prunus amygdalus*) species from Iran and reported that the two species *viz*. *Amygdalus pabotti* (0.26 mg/mL) and *Amygdalus orientalis* (0.33 mg/mL) exhibited the highest antioxidant properties.

Bunea *et al.* [199] analyzed the antioxidant activity in relation to polyphenolic content in some wild and cultivated blueberries from Romania. Results showed that blueberry (*Wild 1* type) extract exhibited the highest total phenolic content (819.12 gallic acid equivalent/100 g fresh weight) and anthocyanin content (300.02 mg/100 g fresh weight), Also, the wild blueberry fruits exhibited higher antioxidant activity with the highest FRAP value of 73.71 μM Fe^{2+}/g and ABTS value of 56.65 μmol TE/g.

Bhuiyan *et al*. [200] evaluated the antioxidant activities of the ethanolic extracts of two varieties of fruits (*Zizyphus mauritiana)* by DPPH assay. Result showed that *Z. mauritiana* (local variety) possessed greater antioxidant activity with an IC_{50} value of 72 µg/mL.

In another study reported by Lamien-Meda *et al*. [201], 14 species of wild edible fruits were assessed for their antioxidant activities using the DPPH, FRAP and ABTS methods. Results showed that among all the tested fruits, the acetone extract of *Detarium microcarpum* fruit exhibited the highest FRAP value (48.45 mmol AEAC/100 g), DPPH free radical scavenging capacity (10729.41 mg AEAC/100 g) and ABTS free radical scavenging capacity (528 µmol AEAC/100 g).

Murillo *et al*. [202] evaluated 39 cultivated and wild edible fruits for their antioxidant activity and total polyphenol content using the DPPH and the Folin-Ciocalteu assays, respectively. Results showed that among the 39 fruits studied, *Ziziphus mauritiania* exhibited the highest antioxidant activity (1083.33 mg TEAC/100 g) and *Anona purpurea* (16.00 mg TEAC/100 g) showed the lowest antioxidant activity.

Luximon *et al*. [203] analyzed 17 commonly consumed fruits from Mauritius for their total phenolics, flavonoids and antioxidant activities. Results revealed that *Psidium cattleianum*, *Syzygium cumini*, *Averrhoa carambola* and *Psidium guajava* fruits exhibited the antioxidant capacities of 47 ± 5 µmol, 15 ± 2 µmol, 17 ± 4 µmol and 17 ± 2 µmol TEAC/g, respectively among the studied fruit species. *Psidium cattleianum* fruit showed the highest levels of total phenolics (5638 ± 364 µg/g) and flavonoid contents (712 ± 32 µg/g).

An edible wild bilberry (*Vaccinium meridionale*) from Colombia was analyzed for total phenolic content, anthocyanin content and antioxidant activity [204]. Results showed that the total phenolic content was 758.6 ± 62.3 mg GAE/100 g and the fruit possessed high antioxidant activity with ABTS value of 45.5 ± 2.3 μmol TE/g and FRAP value of 87.0 ± 17.8 μmol TE/g.

Devi and Mazumder *et al*. [205] reported antioxidant activity of aqueous and ethanol extracts of *Eugenia operculata* fruit and found that the total phenolic content for aqueous and ethanol extracts were 88.1 and 58.6 mg GAE/g. Also, the fruit extract showed potent antioxidant activity with IC_{50} values of 52.96 ± 0.94 and 41.73 ± 0.4 µg/mL for aqueous and ethanol extracts respectively.

Butkhup and Samappito [206] investigated *Antidesma bunius* fruits for their changes in physico-chemical properties, antiradical activity and polyphenolic compounds. Results showed that the total phenolic compounds were in the range from 19.60 to 8.66 mg GAE/g fresh weight and the fruit possess the highest antioxidant activity with an average IC_{50} value of 100.08 μg/mL.

Samappito and Butkhup [207] also examined methanolic extracts of *Antidesma bunius* fruits for flavonoid, anthocyanin, phenolic acids constituents and antioxidant activity. Results indicated that the fruit extracts showed high amounts of flavonoids (397.90 mg/100 g FW), anthocyanin (141.94 mg/100 g DE) and phenolic acid compounds (13.56 mg GAE/g DE). The methanolic extracts of fruits exhibited strong *in vitro* antioxidant activities.

Jorjong *et al.* [208] reported fourteen Mao-Luang (*Antidesma bunius*) cultivars from Northeastern Thailand for their phytochemicals and antioxidant activities. Results indicated that cultivars Kumlai, Sorwamnarsung and Lungplain exhibited the highest levels of phenolic contents (345.68 ± 9.12 mg GAE/100 g DW), flavonoid contents (289.60 ± 19.52 mg catechin equivalent/100 g DW) and total anthocyanin (131.30 mg/100 g DW), respectively. Kumlai also exhibited the highest antioxidant activity with the values of 103.04 mmol vitamin C equivalent antioxidant capacity/g DW (DPPH), 35.35 mmol Fe(II)/g DW (FRAP) and 46.37 mmol trolox equivalent/g DW (ABTS).

Nkafamiya *et al.* [209] investigated the amino acid contents of fruits and leaves of *Azanza garckeana.* The study revealed that two semi-essential (arginine and histidine), seven essential amino acids and eight non-essential amino acids were found in appreciable amounts in both the fruits and leaves. The results indicated the high proteinous content of the plant parts.

The amino acid compositions of the fruits, pulp, peel or seeds from 13 edible and medicinal fruit plant species available in Hong Kong were investigated by Huang *et al.* [210]. The results showed that glutamine was the most common amino acid among the 17 tested amino acids and all the EAAs were detected in all the tested samples. Seeds of sugar apple exhibited the highest value of total amino acids content (14.35%), and also had higher levels of EAAs (arginine = 2.06%; all others ≥0.50% except methionine and histidine). Methionine and cysteine were found with the lowest contents among the tested samples with mean values of 0.02% and 0.03%, respectively.

In another study reported by Ayessou *et al*. [180], amino acid content of wild fruit of *Dialium guineense* from Senegal was analyzed. The results showed that amino acids were present in greater amounts than 0.10 g/100 g which indicates that *Dialium guineense* fruit appears to be a good source of essential amino acids.

An amino acid profile of the African pear (*Dacryodes edulis*) pulp was analyzed by Onuegbu *et al*. [211]. Result showed that the sample contained high amount of leucine and methionine was the lowest among the essential amino acids. The amino acid profiles of the pulp suggest that the pulp can be useful in food formulations and diet.

In addition, Njoku *et al*. [212] studied the amino acid composition of the *Synsepalum dulcificum* berry from Nigeria. It was found that the berry had varying amounts of all the essential amino acids, with leucine having the highest amount and methionine with the lowest value.

Two sumac species *viz*. Chinese sumac (*Rhus typhina* L.) and Syrian sumac (*Rhus coriaria* L.) were investigated by Kossah *et al.* [213] in order to determine the amino acid compositions of the fruits. Results showed that Chinese sumac exhibited higher amounts of essential and non-essential amino acids than that of Syrian sumac.

Amino acid profiles of five bayberry kernels proteins grown in Zhejiang Province, China were analyzed by Cheng *et al.* [214] and found rich in essential amino acids (28.38–29.21%), and their EAAs were comparable to that of FAO/WHO recommended pattern.

Kernels from two wild fruit species *Adansonia digitata* and *Sclerocarya birrea* from Mozambique were analyzed for their amino acid compositions [215]. Results showed that all common amino acids except tryptophan were detected in both types of kernels; glutamic acid being the most abundant amino acid, comprising more than 20% of the protein. The contents of essential amino acids in the kernels were compared with the WHO requirements for children aged 3-10 years. The findings indicated that *Adansonia digitata* and *Sclerocarya birrea* kernels are good sources of protein, especially if combined with foods with high lysine content.

An aqueous extract of wild fruit *Nitraria retusa* was investigated for inhibition of microbial growth [216]. The results indicated that the fruit extract had inhibitory effects against *Bacillus thuringiensis* (17.75 ± 0.35 mm), *Salmonella typhimurium* (15.50 ± 0.02 mm) and *Klebsiella pneumonia* (9.25 ± 0.35 mm), but no inhibitory effects were observed against *Escherichia coli, Aspergillus niger, Bacillus subtilis* and *Rhizopus oryzae*.

Methanol and *n*-hexane extracts of wild mahaleb cherry fruits (*Prunus mahaleb*) were studied by Ozcelik *et al*. [217], by measuring their inhibitory activity on several bacteria (*Escherichia coli, Proteus mirabilis, Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus, Acinetobacter baumannii, Enterococcus faecalis* and *Bacillus* *subtilis*) as well as several fungi (*Candida albicans, Candida tropicalis, Candida parapsilosis* and *Candida krusei*). The results showed that the extracts exhibited antibacterial activities against both Gram (+ve) bacteria (16–64 μg/mL) and Gram (–ve) bacteria (8–64 μg/mL), and the methanol and *n*-hexane extracts demonstrated antifungal activity against *C. krusei* (16–64 μg/mL) with a MIC (minimal inhibition concentration) value of 64 μg/mL. The MIC value of the extracts against all Gram (+ve) and Gram (–ve) isolated strains was 250 μg/mL except *B. subtilis* (64 μg/mL).

In another study reported by Anand *et al*. [218], an aqueous, chloroform and ethanolic extracts of *Catunaregam spinosa* fruit was tested for its antibacterial activity. Results showed that ethanol extracts of *C. spinosa* exhibited maximum zone of inhibition against *Bacillus subtilis* (28.0 mm) followed by *Klebseila pneumonia* (24.0 mm) and *Streptococcus pyogenes* (6 mm) exhibited the lowest zone of inhibition.

An ethanolic extract of a wild fruit (*Ficus auriculata*) was screened for *in vitro* antimicrobial activity by Saklani *et al*. [219] and showed significant activity against *Escherichia coli* (13 ± 1 mm), *Shigella flexneri* (14 ± 1 mm) and *Staphylococcus epidermidis* (12 ± 1 mm).

Hassan *et al.* [220] investigated antimicrobial properties of crude chloroform, hexane and ethanol extracts from fruits of wild melon (*Citrullus lanatus*) against five bacteria (*Escherichia coli, Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Bacillus subtilis* and *Proteus vulgaris*) and two fungi (*C. albican* and *Aspergillus nigar*). It was reported that a chloroform extract of the fruit exhibited the highest antibacterial activity against *Staphylococcus aureus* (36 mm), *Bacillus subtilis* (38 mm), *Escherichia coli* (37 mm), *Proteus vulgaris* (23 mm) and *Pseudomonas aeruginosa* (19 mm), while an ethanol extract of the fruit pulp showed the highest antifungal activity against *Candida albican* (41 mm). It is worth mentioning that this plant acted as potent as standard antimicrobial drugs (gentamicin and clotrimazole) against certain microorganisms.

In a study, Pio-Leon *et al*. [221] tested antimicrobial activity of the three fruits *viz*. *Byrsonima crassifolia, Psidium sartorianum* and *Crescentia alata* by the micro-dilution assay. Results showed that hexane extract of *Psidium sartorianum* and *Crescentia alata* exhibited the highest activity against *Escherichia coli*, *Salmonella* spp. and *Shigella* spp. (MIC = 0.25–2 mg/mL; MBC = 0.5–16 mg/mL). The methanol extract of *Psidium sartorianum* showed the highest activity against Gram (+ve) bacteria, being the most sensitive to *Staphylococcus aureus* (MIC = 2 mg/mL; MBC = 2–4 mg/mL).

In another study, Radovanoviv *et al*. [222] assessed the antimicrobial activities of the polyphenolic extracts of three wild red berry fruits *viz.* European cornel (*Cornus mas*), blackthorn (*Prunus spinosa*) and blackberry (*Rubus fruticosus*) by the disc diffusion method. Results showed that all the tested bacterial strains were inhibited by all the extracts. *Salmonella enteritidis* was reported to be the most sensitive against Gram (–ve) bacteria (14.0 ± 0.9 mm to 1570 ± 1.6 mm), while *Staphylococcus aureus* was found as most sensitive against Gram (+ve) bacteria (13.7 ± 1.3 mm to 14.2 ± 2.2 mm). *Prunus spinosa* extract exhibited slightly higher antimicrobial activity in comparison to other extracts.

An ethanolic fruit extracts of *Myrica nagi* pulp was screened for its antimicrobial activity [223]. This study showed significant activity against *Escherichia coli* (16 ± 1 mm) and *Streptococcus pyogenes* (15 ± 1 mm).

Saklani and Chandra [224] evaluated *in vitro* antimicrobial activity of ethanolic pulp extract of *Pyracantha crenulata* against food poisoning bacteria. Results showed that the extracts exhibited significant activity against *Shigella flexneri* (18 mm), *Escherichia coli* (17 mm) and *Streptococcus pyogenes* (15 mm).

Hendra *et al.* [225] investigated the methanolic extracts of different parts of *Phaleria macrocarpa* fruit for its antimicrobial activity. It was reported that the fruit extracts exhibited variable inhibitory activities against all the tested bacteria with inhibitory zone ranging from 0.93–2.33 cm.

Njoku *et al.* [226] reported anti-nutritional contents of miracle berry (*Synsepalum dulcificum*). The anti-nutrients reported were tannin (2.90 ± 0.64 mg/100 g), oxalate (11.04 ± 0.29%), steroid (1.56 ± 0.03 mg/100 g), phytate (5.21 ± 0.92 mg/100 g) and glycosidic cyanide (0.03 ± 0.00 mg/100 g). Results showed that the anti-nutritional levels were all within the recommended safety limits.

Similarly, the anti-nutritional composition of *Chrysophyllum africanum* fruit was investigated by Edem *et al*. [227]. The study showed that *Chrysophyllum africanum* fruit had a high level of oxalates (4.95%) and saponins (3.66%), a moderate level of cyanogenic glycoside (0.17 %) and a low levels of phytate (0.02%) and tannins (0.03%).

In another study, the anti-nutrient compounds of two variants of *Morus alba* were investigated by Omidiran *et al*. [228]. Results showed that the anti-nutrients such as phytate, tannins and oxalate were present in appreciable amounts with tannin (3.455% and 2.905%), being the highest in the two variants.

Saklani and Chandra [224] reported the phytochemical contents of edible wild fruits of *Pyracantha crenulata* and the composition was reported to be phenolics (1.83%), saponins (1.56%), tannins (0.66%) and flavonoids (3.12%).

The anti-nutritional contents of some wild edible fruits were investigated by Mahadkar *et al*. [229]. The highest tannin content was reported in *Bauhinia recemosa* (0.266 ± 0.005 g/100 g) whereas the highest level of phytate was found in *Oroxylum indicum* (0.04 ± 0.005 g/100 g) and *Bauhinia recemosa* (0.04 ± 0.011 g/100 g). Oxalate content was reported highest in *Oroxylum indicum* and *Zanthoxylum rhetsa* with the same value of 0.06 ± 0.01 g/100 g whereas saponin content was not found in all the fruits.

Adepoju [230] worked on the nutrient composition and anti-nutritional factors of three edible wild fruits *viz*. *Dialium guineense*, *Spondias mombin* and *Mordii whytii*. The highest levels of phytate (1.64 ± 0.04 mg/100 g) and saponin (1.82 + 0.08 mg/100 g) were reported in *M. whytii* fruits whereas the highest levels of oxalate (1.88 ± 0.06 mg/100 g) and tannin (2.41 ± 0.02 mg/100 g) were found in *S. mombin*.

In another study, Umaru *et al*. [231] investigated anti-nutritional factors of sixteen edible wild fruits of Nigeria. The results showed that the high level of phytate was observed in *Haematostaphis barteri* (3.30 ± 0.10%) and *Sclerocarya birrea* (3.56 ± 0.54%). The highest saponin content was reported in *Balanite aegyptiaca* (16.01 ± 0.02%) followed by *Parkia biglobosa* (12.23 ± 0.46%) and *Detarium microcarpum* (12.10 ± 0.05%), while the tannin content was found the highest in *B. aegyptiaca* (7.40 ± 0.14%). The anti-nutritional values reported in the fruits analyzed were below the toxic levels.

Anhwange *et al*. [232] assessed anti-nutritional factors of some indigenous wild fruits such as *Chrysophyllum albidum, Persea americana, Dinnettia tripetala, Diallium guineense, Annona muricata* and *Citrullus lanatus*. The highest levels of tannin was reported in *A. muricata* (65.97 ± 0.02 mg/100 g), whereas low levels alkaloid contents were reported. The highest levels of phytate (0.43 ± 0.00 mg/100 g) and oxalate (0.53 ± 0.00 mg/100 g) were found in *C. albidum.*

The various biological properties of some reported wild edible fruits are presented in **Table I.5**.

Table I.5: Reported wild fruits with biological properties

Wild fruits	**Bioactive compounds**	**Biological property**	**References**
Amygdalus lycioides, Amygdalus pabotti, Amygdalus kotschyi, Amygdalus trichamygdalus	Phenolics	Antioxidant (Radical nitrite, hydrogen peroxide, superoxide radicals)	Isfahlan *et al*. [233]
Cornus mas, Prunus spinosa, Rubus fruticosus	Polyphenolics	Antioxidant (DPPH), Antimicrobial property	Radovanovic *et al*. [234]
Vaccinium angustifolium	Polyphenols and anthocyanins	Antioxidant (FRAP), Anti-cholinesterase activity	Papandreou *et al*. [235]
Crataegus azarolus, Prunus spinosa, Crataegus monogyna, Rosa canina, Rubus ulmifolius, Sorbus domestica	Phenolics and carotenoids	Antioxidant (ABTS and H_2O_2)	Egea *et al*. [236]
Prunus spinosa and *Crataegus monogyna*	Phenolic compounds, ascorbic and dehydroascorbic acids	Antioxidant (DPPH, ABTS and FRAP)	Ruiz-Rodriguez *et al*. [237]
Garcinia pedunculata, Garcinia xanthochymus, Docynia indica, Rhus semialata and *Averrhoa carambola*	Phenolic compounds	Antioxidant (DPPH and ABTS)	Sharma *et al*. [238]
Rubus croceacanthus and *Rubus sieboldii*	Anthocyanins, ascorbic acid	Antioxidant (ORAC)	Kubota *et al*. [239]
Ugni molinae	Polyphenols	Antioxidant (DPPH and ABTS)	Augusto *et al*. [240]

Campomanesia cambessedeana, Byrsonoma verbascifolia, Pouteria guardneriana	Phenolics and flavonoids	Antioxidant (ORAC, peroxyl radicals), Anti-proliferative activity	Malta *et al*. [241]
Genipa americana, Spondia tuberose, Spondia purpurea	Chlorogenic acid	Antioxidant (ABTS), Anti-acetylcholinesterase and cytotoxic activities	Omena *et al.* [242]
Fifteen wild fruits	Polyphenols	Antioxidant (DPPH)	Chalise *et al*. [243]
Salacca edulis Reinw, Garcinia mangostana	Phenolics	Antioxidant (ABTS)	Leontowicz *et al*. [244]
Fragaria indica, Prunus armeniaca, Pyracantha crenulata and *Rubus ellipticus*	Phenolic compounds	Antioxidant (DPPH, ABTS and FRAP)	Saklani *et al*. [80]
Rubus megalococcus, Myrciaria aft cauliflora, Hyeronima macrocarpa	Anthocyanin	Antioxidant (ABTS and DPPH)	Santacruz *et al.* [245]
Arbutus unedo, Rubus ulmifolius	Phenolic acids, anthocyanins and ascorbic acid	Antioxidant (ABTS and DPPH)	Ruiz-Rodriguez *et al*. [246]
Twenty-three wild blueberry fruits	Phenolic compounds	Antioxidant (FRAP and ABTS)	Oszmianski *et al*. [247]
Rubus ulmifolius and *Sambucus nigra*	Phenolics	Antioxidant (DPPH), Anti-inflammatory activity	Fazio *et al*. [248]
wild abiu, acerola, wax jambu, cashew, mamey sapote, carambola or star fruit, surinam cherry, longan, sapodilla and jaboticaba fruits	Phenolics	Antioxidant (hypochlorous acid, ABTS and DPPH)	De Assis *et al.* [249]

Twenty-four exotic Colombian fruits	Phenolics	Antioxidant (ABTS)	Contreras-Calderon *et al*. [250]
Ensete superbum	Phenolics and tannins	Antioxidant (DPPH and ABTS)	Sasipriya *et al*. [251]
Syzygium cumini	Phenolics, tannin, and anthocyanins	Antioxidant (DPPH, hydroxyl radical and superoxide radical)	Banerjee *et al*. [252]
Twelve native Australian fruits	Phenolics and anthocyanins	Antioxidant (ABTS, PCL)	Netzel *et al*. [253]
Eleven exotic fruits from Brazil	Phenolics	Antioxidant (DPPH and ABTS)	Almeida *et al*. [254]

DPPH = 1, 1-diphenyl-2-picrylhydrazyl, FRAP = Ferric reducing antioxidant power, PCL = Photochemiluminescence, ABTS = 2, 2´-azino-bis-3-ethylbenzthiazoline-6-sulphonicacid, ORAC = Oxygen radical absorbance capacity.

North Eastern (NE) region of India which is known for its high biological diversity is often referred to as biological hotspot. NE region comprises eight states *viz*. Assam, Meghalaya, Arunachal Pradesh, Mizoram, Nagaland, Manipur, Tripura including Sikkim which covers an area of 255,083 sq. km representing 7.76% of the country's total geographical area. Assam (89°50′ E to 96°10′ E, 24°30′ N to 28°10′ N) is one of the richest biological diversity zones in NE region of India. The vegetation of NE region has diverse physiography and receives an annual rainfall of maximum 6320 mm. This region forms the richest reservoirs of the plant diversity in India and is one of the biological 'hotspots' of the world supporting about one-third of India's total biodiversity [255]. The region provides excellent sources of fruits and vegetables especially for the consumption of rural population. However, many of the indigenous fruits and vegetables are not being exploited to their fullest potential which still remains underutilized. *Grewia sapida, Eugenia operculata, Aporosa dioica, Antidesma bunius* and *O. alismoides* are the five important and predominant wild edible fruits of this region. These fruits are consumed by the rural people of this region and act as a supplement for their basic needs of food.

I.11 Objectives of present study

The objective of the present investigation was to establish the importance of five wild fruits *viz*. *Grewia sapida, Antidesma bunius, Eugenia operculata, Aporosa dioica* and *Ottelia alismoides* consumed by the rural inhabitants of Assam, India. The study encompasses the following parameters.

1. Analysis of proximate composition
2. Determination of metal contents
3. Phytochemicals screening and evaluation of antioxidant property
4. Study of antimicrobial activity
5. Amino acid analysis
6. Evaluation of anti-nutritional factors

References

[1] Paredes-Lopez O, Cervantes-Ceja ML, Vigna-Perez M, Hernandez-Perez T. Berries: improving human health and healthy aging, and promoting quality life. A review. *Plant Foods Hum. Nutr.* 2010; 65: 299–308.

[2] Eromosele IC, Eromosele CO, Kuzhkzha DM. Evaluation of mineral elements and ascorbic acid contents in fruits of some wild plants. *Plant Foods Hum. Nutr*. 1991; 41: 151–154.

[3] Maikhuri RK, Semwal RL, Singh A, Nautiyal MC. Wild fruit as a contribution to sustainable rural development: A case study from the Garhwal Himalaya. *Inter. J. Sustain. Dev. World. Ecol.* 1994; 1: 56–68.

[4] Aberoumand A, Deokule SS. Studies on nutritional values of some wild edible plants from Iran and India. *Pak. J. Nutr*. 2009; 8: 26–31.

[5] Saka J, Msonthi JD, Maghembe JA. Nutritional value of edible fruits of indigenous wild trees of Malawi. *For. Ecol. Manag*. 1994; 64: 245–248.

[6] Scartezzini P, Speroni E. Review on some plants of Indian traditional medicine with antioxidant activity. *J. Ethnopharmacol.* 2000; 71(1-2): 23–43.

[7] Muthu C, Ayyanar M, Raja N, Ignacimuthu S. Medicinal plants used by traditional healers in Kancheepuram District of Tamil Nadu, India. *J. Ethnobiol. Ethnomed.* 2006; 2: 43.

[8] Rizvi A, Mishra A, Mahdi AA, Ahmad M, Basit A. Natural and herbal stress remedies: A review. *Int. J. Pharmacog*. 2015; 2(4): 155–160.

[9] Vuchi M, Umar A, King M, Liman A, Jeremiah G, Aigbe C. Proximate, vitamins and mineral composition of *Vitex doniana* (black plum) fruit pulp. *Nig. J. Basic Appl. Sci.* 2011; 19: 97–101.

[10] Nesamvuni C, Steyn N, Potgieter M. Nutrient analysis of selected western African foods. *S. Afr. J. Sci*. 2001; 97: 51–54.

[11] Burlingame B. Comparison of total lipids, fatty acids, sugars and nonvolatile organic acids in nuts from *Castanea* species. *J. Food Comp. Anal*. 2000; 13: 99–100.

[12] Sena L, VanderJagt D, Rivera C, Tsin A, Muhammadu I, Mahamadou O, Milson M, Pastosyn A, Glew R. Nutritional profile of some edible plants from Mexico. *Plant Foods Hum. Nutr.* 1998; 52: 17–30.

[13] Edmonds J, Chweya J. Black nightshades, *Solanum nigrum L*. and related species. Promoting the conservation and use of underutilized and neglected crops. Taylor & Francis, London, 1995; 221–234.

[14] Magaia T, Uamusse A, Sjoholm I, Skog K. Dietary fiber, organic acids and minerals in selected wild edible fruits of Mozambique. *Springerplus* 2013; 2(1): 88.

[15] Singh HB, Arora RK. Wild edible plants of India. 1st Ed. New Delhi, ICAR Publication, 1978.

[16] Grivetti LE, Ogle BM. Value of traditional foods in meeting macro- and micro-nutrient needs: the wild plant connection. *Nutr. Res. Rev*. 2000; 13: 31–46.

[17] Padhy C, Behera S. Role of horticulture in human nutrition: An analytical review. *Int. J. Eng. Technol. Manag.* 2015; 3(6): 167–176.

[18] Food and Nutrition Board, Institute of Medicine (US) Subcommittee on Interpretation and Uses of Dietary Reference Intakes; Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Washington (DC): National Academies Press (US), 2000.

[19] Wargovich MJ. Anticancer properties of fruits and vegetables. *Hort. Science* 2000; 35: 573–575.

[20] U.S. Department of Agriculture, U.S. Department of Health and Human Services. Nutrition and Your Health: Dietary Guidelines for Americans, 5th Ed. Home and Garden Bull. 232, U.S. Government Printing Office, Washington, DC, 2000.

[21] Kalt W. Health functional phytochemicals of fruits. *Hort. Rev*. 2002; 27: 269–315.

[22] Southon S. Increased fruit and vegetable consumption within the EU: potential health benefits. *Food Res. Intl*. 2000; 33: 211–217.

[23] Seifried HE, McDonald SS, Anderson DE, Greenwald P, Milner JA. The antioxidant conundrum in cancer. *Cancer Res*. 2003; 63: 4295–4298.

[24] Tohill BC, Seymour J, Serdula M, Kettel-Khan L, Rolls BJ. What epidemiological studies tell us about the relationship between fruit and vegetable consumption and body weight? *Nutr. Rev*. 2004; 62: 365–374.

[25] He FJ, Nowson CA, Macgregor GA (2006). Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. *Lancet* 2006; 367: 320–326.

[26] Ness AR, Powles JW. Fruit and vegetables and cardiovascular disease: A review. *Int. J. Epidemiol*. 1997; 26 (1): 1–13.

[27] Alonso A, de la Fuente C, Martin-Arnau AM, de Irala J, Martinez JA, Gonzalez MA. Fruit and vegetable consumption is inversely associated with blood pressure in a Mediterranean population with a high vegetable-fat intake. *Brit. J. Nutr*. 2004; 92: 311–319.

[28] Galeone C, Negri E, Pelucchi C. Dietary intake of fruits and vegetables and lung cancer risk: a case-control study in Harbin, Northern China. *Ann. Oncol*. 2007; 18: 388–392.

[29] Lin PH, Ginty F, Appel LJ. The DASH diet and sodium reduction improve markers of bone turnover and calcium metabolism in adults. *J. Nutr*. 2003; 133 (10): 3130–3136.

[30] Lock K, Pomerleau J, Causer L, Altmann DR, McKee M (2005). The global burden of disease attributable to low consumption of fruit and vegetables: Implications for the global strategy on diet. *World Health Org*. 2005; 83: 100–108.

[31] Habauzit V, Milenkovic D, Morand C. Vascular Protective Effects of Fruit Polyphenols. In. Polyphenols in Human Health and Disease. Eds, Watson R, Preedy V, Zibadi S. 1st Ed., Elsevier Inc. London, 2013; 875–893.

[32] Park HM, Heo J, Park Y. Calcium from plant sources is beneficial to lowering the risk of osteoporosis in postmenopausal Korean women. *Nutr. Res*. 2011; 31: 27–32.

[33] Shen CL, Bergen VV, Chyu MC, Jenkins MR, Mo H, Chen CH, Kwun IS. Fruits and dietary phytochemicals in bone protection. *Nutr. Res*. 2012; 32: 897–910.

[34] Mccrory MA, Fuss PJ, Saltzman E, Roberts SB. Dietary determinants of energy intake and weight regulation in healthy adults. *J. Nutr*. 2000; 130: 276–279.

[35] Malik J, Szakova J, Drabek O, Balik J, Kokoska L. Determination of certain micro and macro-elements in plant stimulants and their infusions. *Food Chem*. 2008; 111: 520–525.

[36] Insel P, Ross D, McMahon K, Bernstein M. Nutrition, Sudbury Massachusetts, USA: Jones and Bartlett Publishers, 2011.

[37] Imelouane B, Tahri M, Elbastrioui M, Aouinti F, Elbachiri A. Mineral contents of some medicinal and aromatic plants growing in Eastern Morocco. *J. Mater. Environ. Sci*. 2011; 2(2): 104–111.

[38] Fraga CG. Relevance, essentiality and toxicity of trace elements in human health. *Mol. Aspects Med*. 2005; 26(4): 235–244.

[39] Sanchez-Castillo CP, Dewey PJS, Aguirre A, Lara JJ, Vaca R, de la Barra PL, Ortiz M, Escamilla I, James WPT. The mineral content of Mexican fruits and vegetables. *J. Food Compos. Anal*. 1998; 11: 340–356.

[40] Baysal A. Fundamentals of Nutrition, Hatipoglu Press, Ankara (in Turkish), 2002.

[41] Black R. Micronutrient deficiency-an underlying cause of morbidity and mortality. *Bull. World Health Organ*. 2003; 81(2): 79.

[42] Khan N, Choi JY, Nho EY, Jamila N, Habte G, Hong JH, Hwang IM, Kim KS. Determination of minor and trace elements in aromatic spices by micro-wave assisted digestion and inductively coupled plasma-mass spectrometry. *Food Chem*. 2014; 158: 200–6.

[43] Llorent-Martinez EJ, De Cordova MLF, Ruiz-Medina A, Ortega-Barrales P. Analysis of 20 trace and minor elements in soy and dairy yogurts by ICP-MS. *Microchem. J.* 2012; 102(1): 23–27.

[44] Murray RK, Granner DK, Mayes PA, Rodwell VW. Harper's Biochemistry, 25th Edition, McGraw-Hill, Health Profession Division, USA. 2000.

[45] Soetan CO, Olaiya CO, Oyewole OE. The importance of mineral elements for humans, domestic animals and plants: A review. *Afr. J. Food Sci*. 2010; 4(5): 200–222.

[46] Malhotra VK. Biochemistry for Students. 10th Edition. Jaypee Brothers Medical Publishers (P) Ltd, New Delhi, India, 1998.

[47] McCarron DA, Reusser ME. Are low intakes of calcium and potassium important causes of cardiovascular disease? *Am. J. Hypertens*. 2001; 14: 206–212.

[48] Ignarro LJ, Balestrieri ML, Napoli C. Nutrition, physical activity, and cardiovascular disease: An update. *Cardiovasc. Res.* 2007; 73: 326–340.

[49] Zerwekh JE, Odvina CV, Wuermser LA, Pak CY. Reduction of renal stone risk by potassium-magnesium citrate during 5 weeks of bed rest. *J. Urol*. 2007; 177: 2179–2184.

[50] Adamkova A, Kourimska L, Borkovcova M, Mlcek J, Bednarova M. Calcium in edible insects and its use in human nutrition. *Potravinarstvo – The Scientific Journal for Food Industry* 2014; 8: 233–238.

[51] Food and Nutrition Board. Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. Washington, DC: National Academy Press, 1997.

[52] National Institutes of Health, Office of Dietary Supplements. Magnesium fact sheet for health professionals, 2013.

[53] Stipanuk MH, Caudill MA. Biochemical, Physiological and Molecular Aspects of Human Nutrition. 3rd Ed. Elsevier Saunders Publishing, Philadelphia, 2012.

[54] Andrews NC, Fleming MD, Levy JE, Molecular insights into mechanisms of iron transport. *Curr. Opin. Hematol*. 1999; 6(2): 61–4.

[55] Hurrell R, Egli I. Iron bioavailability and dietary reference values. *Am. J. Clin. Nutr*. 2010; 91(5): 1461–1467.

[56] Smith C, Mitchinson MJ, Aruoma OI, Halliwell B. Stimulation of lipid peroxidation and hydroxyl-radical generation by the contents of human atherosclerotic lesions. *Biochem. J*. 1992; 286(3): 901–5.

[57] Bhuvaneswari S, Joshi M, D'Souza A. Quantitative Analysis of Iron and Ascorbic acid contents in locally consumed Fruits and Vegetables. *Int. Res. J. Biological Sci*. 2015; 4(7): 42–47.

[58] Rabin O, Hegedus L, Bourre JM, Smith QR. Rapid brain uptake of manganese (II) across the blood–brain barrier. *J. Neurochem*. 1993; 61(2): 509–517.

[59] Aschner M. Manganese: Brain transport and emerging research needs. *Environ. Health Perspect*. 2000; 108 (3): 429–432.

[60] Squitti R, Polimanti R. Copper phenotype in Alzheimer's disease: Dissecting the pathway. *Am. J. Neurodegener*. *Dis*. 2013; 2(2): 46–56.

[61] Letelier ME, Faundez M, Jara-Sandoval J, Molina-Berrios A, Cortes-Troncoso J, Aracena-Parks P, Marin-Catalan R. Mechanisms underlying the inhibition of the cytochrome P_{450} system by copper ions. *J. Appl. Toxicol*. 2009; 29: 695–702.

[62] Solomons NW. Mild human zinc deficiency produces an imbalance between cell-mediated and humoral immunity. *Nutr. Rev*. 1998; 56: 27–28.

[63] Fabris N, Mocchegiani E. Zinc, human diseases and aging. *Aging* 1995; 7: 77–93.

[64] Hojyo S, Fukada T. Roles of Zinc signaling in the immune system. *J. Immunol. Res*. 2016; 2016.

[65] Bitanihirwe BK, Cunningham MG. Zinc: The brain's dark horse. *Synapse* 2009; 63: 1029.

[66] Udechukwu MC, Collins SA, Udenigwe CC. Prospects of enhancing dietary zinc bioavailability with food-derived zinc-chelating peptides. *Food Funct*. 2016; 7: 4137–4144.

[67] Kawahara M, Tanaka KI, Kato-Negishi M. Zinc, Carnosine, and Neurodegenerative Diseases. *Nutrients* 2018; 10(2): 147.

[68] Barceloux GD. Manganese, nickel. *Clin. Toxicol*. 1999; 37: 239–258.

[69] Arinola OG, Nwozo SO, Ajiboye JA, Oniye AH. Evaluation of trace elements and total antioxidant status in Nigerian cassava processors. *Pak. J. Nutr*. 2008; 7(6): 770–772.

[70] Rivas CI, Vera JC, Guaiquil VH, Velasquez FV, Borquez-Ojeda OA, Carcamo JG, Concha II, Golde DW. Increased uptake and accumulation of vitamin C in human immunodeficiency virus 1-infected hematopoietic cell lines. *J. Biol. Chem*. 1997; 272 (9): 5814–5820.

[71] Cathcart RF. A unique function for ascorbate. *Med. Hypotheses* 1991; 35: 32–37.

[72] Beyer RE. The role of ascorbate in antioxidant protection of biomembrane: Interaction with vitamin E and coenzyme Q. *J. Bioenerg. Biomembr*. 1994; 26: 349–358.

[73] Talaulikar VS, Manyonda IT. Vitamin C as an antioxidant supplement in women's health: A myth in need of urgent burial. *Eur. J. Obstet. Gynecol. Reprod. Biol*. 2011; 157: 10–13.

[74] Pignocchi C, Foyer CH. Apoplastic ascorbate metabolism and its role in the regulation of cell signaling. *Curr. Opin. Plant Biol*. 2003; 6(4): 379–389.

[75] Smirnoff N, Wheeler GL. Ascorbic acid in plants: Biosynthesis and function. *Crit. Rev. Plant Sci*. 2000; 19(4): 267–290.

[76] Packer JE, Slater TF, Willson RL. Direct observation of a free radical interaction between vitamin E and vitamin C. *Nature* 1979; 278: 737–738.

[77] Tanaka K, Hashimoto T, Tokumaru S, Iguchi H, Kojo S. Interactions between vitamin C and vitamin E are observed in tissues of inherently scorbutic rats. *J. Nutr*. 1997; 127: 2060–2064.

[78] Beck K, Conlon CA, Kruger R, Coad J, Stonehouse W. Gold kiwifruit consumed with an iron-fortified breakfast cereal meal improves iron status in women with low iron stores: A 16-week randomised controlled trial. *Br. J. Nutr*. 2011; 105: 101–109.

[79] Narasinga R. Bioactive phytochemicals in Indian foods and their potential in health promotion and disease prevention. *Asia Pac. J. Clin. Nutr*. 2003; 12 (1): 9–22.

[80] Saklani S, Badhani A, Mishra AP, Chandra S. Health promoting phytochemicals their concentration and antioxidant activity of wild edible fruits of Uttarakhand, India. *Asian. J. Chem*. 2012; 24: 5558–5560.

[81] Rao BN. Bioactive phytochemicals in Indian foods and their potential in health promotion and disease prevention. *Asia Pac. J. Clin. Nutr*. 2003; 12 (1): 9–22.

[82] Liu RH. Potential synergy of phytochemicals in cancer prevention: Mechanism of action. *J. Nutr*. 2004; 134: 3479–85.

[83] Parimala M, Shoba FG. *In vitro* antimicrobial activity and HPTLC analysis of hydroalcoholic seed extract of *Nymphaea nouchali* Burm. f. *BMC Complement Alt. Med*. 2014; 14: 361.

[84] Amoo SO, Ndhlala AR, Finnie JF, Van Staden J. Antifungal, acetylcholinesterase inhibition, antioxidant and phytochemical properties of three *Barleria* species. *South Afr. J. Bot*. 2011; 77: 435–45.

[85] Balasundram N, Sundram K, Samman S. Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chem*. 2006; 99: 191–203.

[86] Del Rio D, Rodriguez-Mateos A, Spencer JPE, Tognolini M, Borges G, Crozier A. Dietary (poly) phenolics in human health: Structures, bioavailability, and evidence of protective effects against chronic diseases. *Antioxid. Redox Signal* 2013; 18: 1818–1892.

[87] Ayoub M, de Camargo AC, Fereidoon S. Antioxidants and bioactivities of free, esterified and insoluble-bound phenolics from berry seed meals. *Food Chem*. 2016; 197: 221–232.

[88] Valenzuela A, Nieto S, Cassels BK, Speisky H. Inhibitory effect of boldine on fish oil oxidaton. *J. Am. Oil Chem. Soc*. 1992; 68(12): 935–937.

[89] Gordon MH. Dietary antioxidants in disease prevention. *Nat. Prod. Rep*. 1996; 13(4): 265–73.

[90] Waterman PG, Mole S. Analysis of Phenolic Plant Metabolites. Blackwell Scientific Publications. Oxford, 1994.

[91] Zheng J, Zhou Y, Li S, Zhang P, Zhou T, Xu DP, Li HB. Effects and mechanisms of fruit and vegetable juices on cardiovascular diseases. *Int. J. Mol. Sci*. 2017; 18(3): 555.

[92] Prakash D, Kumar N. Cost Effective Natural Antioxidants. In: Watson RR, Gerald JK, Preedy VR (eds), Nutrients, Dietary Supplements and Nutraceuticals. Humana Press, Springer, USA, 2011; 163–188.

[93] Kasangana PB, Haddad PS, Stevanovic T. Study of polyphenol content and antioxidant capacity of *Myrianthus Arboreus* (Cecropiaceae) root bark extracts. *Antioxidants* 2015; 4(2): 410–26.

[94] Surai PF. Silymarin as a natural antioxidant: An overview of the current evidence and perspectives. *Antioxidants* 2015; 4(1): 204–247.

[95] Halliwell B. Reactive oxygen species in living systems: Source, biochemistry, and role in human disease. *Am. J. Med*. 1991; 91(3): 14–22.

[96] Young IS, Woodside JV. Antioxidants in health and disease. *J. Clin. Pathol*. 2001; 54(3): 176–186.

[97] Devasagayam TPA, Tilak JC, Boloor KK, Sane KS, Ghaskadbi SS, Lele RD. Free radicals and antioxidants in human health: Current status and future prospects. *J. Assoc. Physicians India* 2004; 52: 794–804.

[98] Cai YZ, Sun M, Corke H. Antioxidant activity of betalains from plants of the amaranthaceae. *J. Agric. Food Chem*. 2003; 51(8): 2288–2294.

[99] Kaur C, Kapoor HC. Antioxidant activity and total phenolic content of some Asian vegetables. *Int. J. Food Sci. Tech*. 2002; 37: 153–162.

[100] Sies H. Strategies of antioxidant defense. *Eur. J. Biochem*. 1993; 215: 213–219.

[101] Halliwell B. Free radicals, antioxidants, and human disease: Curiosity, cause, or consequence? *Lancet* 1994; 344: 721–724.

[102] Kozarski MS, Klaus AS, Niksic MP, van Griensven LJLD, Vrvic MM, Jakovljevic DM. Polysaccharides of higher fungi: Biological role, structure and anti-oxidative activity. *Chem. Ind*. 2014; 68: 305–320.

[103] Anagnostopoulou MA, Kefalas P, Papageorgiou VP, Assimopoulou AN, Boskou D. Radical scavenging activity of various extracts and fractions of sweet orange peel (*Citrus sinensis*). *Food Chem*. 2006; 94: 19–25.

[104] Schuler P. Natural antioxidants exploited commercially, In: Hudson BJF, Ed., Food Antioxidants, Elsevier, London, 1990; 99–170.

[105] Klipstein-Grobusch K, Launer LJ, Geleijnse JM, Boeing H, Hofman A, Witterman JC. Serum carotenoids and atherosclerosis. The Rotterdam study. *Atherosclerosis* 2000; 148(1): 49–56.

[106] Chu Y. Flavonoid content of several vegetables and their antioxidant activity. *J. Sci. Food Agric*. 2000; 80: 561–566.

[107] Christensen LP, Brandt K. Acetylenes and Psoralens. In Plant Secondary Metabolites: Occurrence, Structure, and Role in the Human Diet, Crozier A, Clifford MN, Ashihara H. Wiley-Blackwell: Oxford, UK, 2006; 147–163.

[108] Cetkovic GS, Canadanovic-Brunet JM, Djilas SM, Tumbas VT, Markov SL, Cvetkovic DD. Antioxidant potential, lipid peroxidation inhibition and antimicrobial activities of *Satureja montana* L. subsp. *Kitaibelii* extracts. *Int. J. Mol. Sci*. 2007; 8: 1013–1027.

[109] World Health Organization. Antimicrobial resistance. Antimicrob. Resist. Glob. Rep. surveillance. Geneva, WHO Press, 2014.

[110] Cowan MM. Plant products as antimicrobial agents. *Clin. Microbiol. Rev*. 1999; 12: 564–582.

[111] Savoia D. Plant-derived antimicrobial compounds: Alternatives to antibiotics. *Future Microbiol*. 2012; 7(8): 979–90.

[112] Upadhyay A, Upadhyaya I, Kollanoor-Johny A, Venkitanarayanan K. Combating pathogenic microorganisms using plant-derived antimicrobials: A mini-review of the mechanistic basis. *Biomed. Res. Int*. 2014; 2014: 1–18.

[113] Geissman T. Flavonoid compounds, tannins, lignins and related compounds. In: Florkin M, Stotz EH, editors. Pyrrole pigments, isoprenoid compounds and phenolic plant constituents. Elsevier, New York, 1963; 9: 265.

[114] Scalbert A. Antimicrobial properties of tannins. *Phytochemistry* 1991; 30: 3875–3883.

[115] Bennett RN, Wallsgrove RM. Secondary metabolites in plant defense mechanisms. *New Phytologist* 1994; 127: 617–633.

[116] Chung KT, Stevens SEJ, Lin WF, Wei CI. Growth inhibition of selected foodborne bacteria by tannic acid, propyl gallate and related compounds. *Lett. Appl. Microbiol*. 1993; 17: 29–32.

[117] Prusti A, Mishra SR, Sahoo S, Mishra SK. Antibacterial activity of some Indian medicinal plants. *Ethnobot. Leaflets* 2008; 12: 227–230.

[118] Silver LL, Bostian KA. Discovery and development of new antibiotics: The problem of antibiotic resistance. *Antimicrob. Agents Chemother*. 1993; 37(3): 377–383.

[119] Galli F. Amino acid and protein modification by oxygen and nitrogen species. *Amino Acids* 2007; 32: 497–499.

[120] Suenaga R, Tomonaga S, Yamane H, Kurauchi I, Tsuneyoshi Y, Sato H, Denbow DM, Furuse M. Intracerebroventricular injection of L-arginine induces sedative and hypnotic effects under an acute stress in neonatal chicks. *Amino Acids* 2008; 35: 139–146.

[121] Wu G. Amino acids: metabolism, functions, and nutrition. *Amino Acids* 2009; 37: 1–17.

[122] Elango R, Ball RO, Pencharz PB. Amino acid requirements in humans: with a special emphasis on the metabolic availability of amino acids. *Amino Acids* 2009; 37: 19–27.

[123] Wu G. Functional amino acids in growth, reproduction and health. *Adv. Nutr*. 2010; 1(1): 31–37.

[124] Wu G. Functional amino acids in nutrition and health. *Amino Acids* 2013; 45(3): 407–411.

[125] WHO/FAO/UNU Expert Consultation. Proteins and amino acids in human nutrition. World Health Organisation technical report series. 2007; 935: 265.

[126] Wu G, Wu ZL, Dai ZL, Yang Y, Wang WW, Liu C, Wang B, Wang JJ, Yin YL. Dietary requirements of “nutritionally nonessential amino acids” by animals and humans. *Amino Acids* 2013; 44: 1107–1113.

[127] Hou Y, Yin Y, Wu G. Dietary essentiality of “nutritionally non-essential amino acids” for animals and humans. *Exp. Biol. Med*. 2015; 240(8): 997–1007.

[128] Wang WW, Wu ZL, Dai ZL, Yang Y, Wang JJ, Wu G. Glycine metabolism in animals and humans: Implications for nutrition and health. *Amino Acids* 2013; 45: 463–77.

[129] Zandifar A, Seifabadi S, Zandifar E, Beheshti SS, Aslani A, Javanmard SH. Comparison of the effect of topical versus systemic L-arginine on wound healing in acute incisional diabetic rat model. *J. Res. Med. Sci*. 2015; 20(3): 233–238.

[130] De Bandt JP, Cynober L. Therapeutic use of branched chain amino acids in burn, trauma, and sepsis. *J. Nutr*. 2006; 185(1): 308–313.

[131] World Health Organization. Protein and amino acid requirements in human nutrition: report of a joint FAO/WHO/UNU expert consultation. Tech. Rep. Series no. 935, WHO, Geneva, Switzerland, 2002.

[132] Selhub J, Troen AM. Sulfur amino acids and atherosclerosis: A role for excess dietary methionine. *Ann. N Y Acad. Sci*. 2015; 1363(1): 18–25.

[133] Rai S, Hare DL, and Zulli A. A physiologically relevant atherogenic diet causes severe endothelial dysfunction within 4 weeks in rabbit. *Int. J. Exp. Pathol*. 2009; 90(6): 598–604.

[134] Mischoulon D, Fava M. Role of S-adenosyl-L-methionine in the treatment of depression: A review of the evidence. *Am. J. Clin. Nutr*. 2002; 76(5): 1158–61.

[135] Richard DM, Dawes MA, Mathias CW, Acheson A, Hill-Kapturczak N, Dougherty DM. L-tryptophan: Basic metabolic functions, behavioral research and therapeutic indications. *Int. J. Tryptophan Res*. 2009; 2(1): 45–60.

[136] Liao SM, Du QS, Meng JZ, Pang ZW, Huang RB. The multiple roles of histidine in protein interactions. *Chem. Cent. J*. 2013; 7(1): 44.

[137] Chen C, Sander JE, Dale NM. The effect of dietary lysine deficiency on the immune response to Newcastle disease vaccination in chickens. *Avian Dis*. 2003; 47(4): 1346–1351.

[138] Vianey-Liaud C, Divry P, Poinas C, Mathieu M. Lysine metabolism in man. *Ann. Biol. Clin*. 1991; 49(1): 18–26.

[139] Sapolsky R. Biology and Human Behavior: The Neurological Origins of Individuality. The Teaching Company, 2nd edition, 2005.

[140] Chen PE, Geballe MT, Stansfeld PJ, Johnston AR, Yuan H, Jacob AL, Snyder JP, Traynelis SF, Wyllie DJ. Structural features of the glutamate binding site in recombinant NR1/NR2A N-methyl-D-aspartate receptors determined by site-directed mutagenesis and molecular modeling. *Mol. Pharmacol*. 2005; 67(5): 1470–1484.

[141] Jobgen WS, Fried SK, Fu WJ, Meininger CJ, Wu G. Regulatory role for the arginine-nitric oxide pathway in metabolism of energy substrates. *J. Nutr. Biochem*. 2006; 17: 571–588.

[142] Kayode RMO, Olakulelim TF, Adedeji BS, Ahmed O, Aliye TH, Badmos AHA. Evaluation of amino acid and fatty acid profile of commercially cultivated oyster mushroom (*Pleurotus sajor-caju*) grown on gmelina wood waste. *Nig. Food J*. 2015; 33(1): 18–21.

[143] Hyland K. Inherited disorders affecting dopamine and serotonin: Critical neurotransmitters derived from aromatic amino acids. *J. Nutr*. 2007; 137(6): 1568–1572.

[144] Mahapatra AK, Mishra S, Basak UC, Panda PC. Nutrient analysis of some selected wild edible fruits of deciduous forests of India: An explorative study towards non-conventional bio-nutrition. *Adv. J. Food Sci. Technol.* 2012; 4: 15–21.

[145] Binita R, Khetarpaul N. Probiotic fermentation: Effect on anti-nutrients and digestability of starch and protein of indigenous developed food mixture. *J. Nutr. Health* 1997; 11(3): 139–47.

[146] Bardocz S, Gelencser E, Pusztai A. Effects of anti-nutrients on the nutritional value of legume diets. Vol.1, Brussels, 1996.

[147] Soetan K, Oyewol O. The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. *Afr. J. Food Sci*. 2009; 3(9): 223–232.

[148] Muzquiz M. Recent advances of research in anti-nutritional factors in legume seeds and oil seeds. EAAP publications No.110. Toledo, Spain, 2004.

[149] Valvi SR, Rathod VS, Anti-nutritional factors of some wild edible fruits from Kolhapur district. *Recent Res. Sci. Technol*. 2011; 3: 68–72.

[150] Panhwar. Anti-nutritional factors in oil seeds as aflatoxin in ground nut. Digitalverlag GmbH, Germany, 2005; 1–7.

[151] Abirami A, Nagarani G, Siddhuraju P. *In vitro* antioxidant, anti-diabetic, cholinesterase and tyrosinase inhibitory potential of fresh juice from *Citrus hystrix* and *C. maxima* fruits. *Food Sci. Hum. Well*. 2014; 3: 16–25.

[152] Habtamu F, Negussie R. Anti-nutritional factors in plant foods: Potential health benefits and adverse effects. *Int. J. Nutr. Food Sci*. 2014; 3(4): 284–289.

[153] Olayemi FO. A review on some causes of male infertility. *Afr. J. Biotechnol*. 2010; 9(20): 2834–3842.

[154] Smitha Patel PA, Alagundagi SC, Salakinkop SR. The anti-nutritional factors in forages. A review. *Current Biotica*. 2013; 6(4): 516–526.

[155] Reddy NR, Pierson MD, Sathe SK, Salunkhe DK. Dry bean tannins: A review of nutritional implications. *J. Am. Oil Chem. Soc.* 1985; 62(3): 541–549.

[156] Oleszek WA. Chromatographic determination of plant saponins. *J. Chromatogr*. 2002; 967: 147–162.

[157] Kao TH, Huang SC, Inbaraj BS, Chen BH. Determination of flavonoids and saponins in *Gynostemma pentaphyllum* (Thunb.) Makino by liquid chromatography-mass spectrophotometry. *Anal. Chim. Acta*. 2008; 626: 200–211.

[158] Kwok J. Cyanide poisoning and cassava, in: Food safety focus, 19th Issue. Centre for Food Safety. The Government of Hong Kong, 2008.

[159] FAO/WHO. WHO Food Additive Series: 65. Safety evaluation of certain food additives and contaminants. Prepared by the 74th Meeting of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization, Geneva, 2012.

[160] Haque MR, Bradbury JH. Total cyanide determination of plants and foods using the picrate and acid hydrolysis methods. *Food Chem*. 2002; 77: 107–114.

[161] D'Mello JPF. Anti-nutritional factors and mycotoxins. In: Farm animal metabolism and nutrition. CAB International Wallingford, UK, 2000; 383–403.

[162] Libert B, Franceschi VR. Oxalate in crop plants. *J. Agric. Food Chem*. 1987; 35(6): 926–937.

[163] Ladeji O, Akin CU, Umaru HA. Level of anti-nutritional factors in vegetables commonly eaten in Nigeria. *Afr. J. Nat. Sci*. 2004; 7: 71–73.

[164] Graf E, Eaton JW. Antioxidant functions of phytic acid. *Free Radic. Biol. Med*. 1990; 8(1): 61–69.

[165] Weaver CM, Kannan S. Phytate and mineral bioavailability. In: Reddy NR, Sathe SK (Eds.), Food phytates, CRC Press, Boca Raton, FL, USA, 2002; 211–223.

[166] Phillippy BQ. Inositol phosphates in foods. *Adv. Food Nutr. Res*. 2003; 45: 1–60.

[167] Hathcock JN. Residue Trypsin Inhibitor: Data Needs for Risk Assessment. In: Friedman M. (eds.) Nutritional and Toxicological Consequences of Food Processing. *Adv. Exp. Med. Biol*, vol. 289. Springer, Boston, MA, 1991.

[168] Liener IE. Implications of anti-nutritional components in soybean foods. *Crit. Rev. Food Sci. Nutr*. 1994; 34(1): 31–67.

[169] Kumar BD, Mitra A, Manjunatha M. A comparative study of alpha-amylase inhibitory activities of common anti-diabetic plants of Kharagpur 1 block. *Int. J. Green Pharm*. 2010; 4: 115–21.

[170] Franco OL, Rigden DJ, Melo FR, Grossi-de-sa MF. Plant α-amylase inhibitors and their interaction with insect α-amylases structure, function and potential for crop protection. *Eur. J. Biochem*. 2002; 269: 397–412.

[171] Bhat M, Zinjarde SS, Bhargava SY, Kumar AR, Joshi BN. Anti-diabetic Indian plants: A good source of potent amylase inhibitors. *Evid. Based Complement Alternat. Med*. 2011; 2011: 810207.

[172] Judprasong K, Charoenkiatkul S, Thiyajai P, Sukprasansap M. Nutrients and bioactive compounds of Thai indigenous fruits. *Food Chem*. 2013; 140: 507–512.

[173] Hoe VB, Siong KH. The nutritional value of indigenous fruits and vegetables in Sarawak. *Asia Pac. J. Clin. Nutr*. 1999; 8(1): 24–31.

[174] Magaia T, Uamusse A, Sjoholm I, Skog K. Proximate analysis of five wild fruits of Mozambique. *Sci. World J*. 2013: 601435.

[175] Salih NK-EM, Yahia EM. Nutritional value and antioxidant properties of four wild fruits commonly consumed in Sudan. *Int. Food Res. J.* 2015; 22(6): 2389–2395.

[176] Osman MA. Chemical and nutrient analysis of baobab (*Adansonia digitata*) fruit and seed protein solubility. *Plant Foods Hum. Nutr.* 2004; 59(1): 29–33.

[177] Salih OM, Nouf AM, Harperb DB. Chemical and nutritional composition of two famine food sources used in Sudan, mukheit (*Boscia senegalensis*) and maikah (*Dobera roxburghi*). *J. Sci. Food Agric*. 1991; 57: 367–377.

[178] Marakoglu T, Arslan D, Ozcan M, Haciseferogullari H. Proximate composition and technological properties of fresh blackthorn (*Prunus spinosa* L. subsp *dasyphylla* (Schur.)) fruits. *J. Food Eng*. 2005; 68(2): 137–142.

[179] Satpathy G, Tuagi YK, Gupta RK. Preliminary evaluation of nutraceutical and therapeutic potential of raw *Spondias pinnata* K., an exotic fruit of India. *Food Res. Int*. 2011; 44: 2076–2087.

[180] Ayessou NC, Ndiaye C, Ciss M, Gueye M, Sakho M, Dornier M. Nutrient composition and nutritional potential of wild fruit *Dialium guineense*. *J. Food Compos. Anal*. 2014; 34: 186–191.

[181] Agrahar-Murugkar D, Subbulakshmi G. Nutritive values of wild edible fruits, berries, nuts, roots and spices consumed by the Khasi tribes of India. *Ecol. Food Nutr*. 2005; 44(3): 207–223.

[182] Seal T. Evaluation of Nutritional Potential of Wild Edible Plants, Traditionally used by the Tribal People of Meghalaya State in India. *Am. J. Plant Nutr. Fertil. Technol*. 2012; 2(1): 19–26.

[183] Sadia H, Mushtaq A, Shazia S, Ahmad Zuhairi A, Lee KT, Muhammad Z, Asghari B. Nutrient and mineral assessment of edible wild fig and mulberry fruits. *Fruits* 2014; 69(2): 159–166.

[184] Maikhuri RK, Dhyani D, Tyagi Y, Singh D, Negi VS, Rawat LS. Determination of nutritional and energy value of *Viburnum mullaha* Buch.-Ham. Ex D. Don (Indian cranberry). *Ecol. Food Nutr*. 2012; 51: 218–226.

[185] Leterme P, Buldgen A, Estrada F, Londono AM. Mineral content of tropical fruits and unconventional foods of the Andes and the rain forest of Colombia. *Food Chem*. 2006; 95: 644–652.

[186] Arunachalam K, Murugan R, Parimelazhagan T. Evaluation of antioxidant activity, nutritional and chemical composition of *Ficus amplissima* Smith. Fruit. *Int. J. Food Prop*. 2014; 17: 454–468.

[187] Calisir S, Haciseferogullari H, Ozcan M, Arsalan D. Some nutritional and technological properties of wild plum (*Prunus spp.*) fruit in Turkey. *J. Food Eng*. 2005; 66: 223–237.

[188] Olayiwola IO, Akinfewa V, Oguntona C, Sanni S, Onabanjo O, Afolabi WA. Phytonutrient, antioxidant and mineral composition of some wild fruits in south west Nigeria. *Niger. Food J*. 2013; 31(2): 33–40.

[189] Valvi SR, Rathod VS. Mineral composition of some wild edible fruits from Kolhapur district. *Int. J Appl. Biol. Pharm*. 2011; 2(1): 392.

[190] Renna M, Cocozza C, Gonnella M, Abdelrahman H, Santamaria P. Elemental characterization of wild edible plants from countryside and urban areas. *Food Chem*. 2015; 177: 29–36.

[191] Saklani S, Chandra S, Kandari SA. *Berberis asiatica* future based excellent fruit in nutritional profile, antimicrobial and antioxidant ingredients. *Int. Res. J. Pharm*. 2011; 2(12): 213–216.

[192] Llorent-Martinez EJ, Spinola V, Castilho PC. Evaluation of the inorganic content of six underused wild berries from Portugal: Potential new sources of essential minerals. *J. Food Compos. Anal*. 2017; 59: 153–160.

[193] Glew RH, Ayaz FA, Vanderjagt DJ, Millson M, Dris R, Niskanen R. A Research note mineral composition of medlar (*Mespilus germanica*) fruit at different stages of maturity. *J. Food Qual*. 2003; 26: 441–447.

[194] Barreca D, Lagana G, Ficarra S, Tellone E, Leuzzi U, Galtieri A, Bellocco E. Evaluation of the antioxidant and cytoprotective properties of the exotic fruit *Annona cherimola* Mill. (Annonaceae). *Food Res. Int*. 2011; 44: 2302–2310.

[195] Zheng J, Ding C, Wang L, Li G, Shi J, Li H, Wang H, Suo Y. Anthocyanins composition and antioxidant activity of wild *Lycium ruthenicum* Murr. from Qinghai-Tibet Plateau. *Food Chem*. 2011; 126: 859–865.

[196] Rawat S, Jugran A, Giri L, Bhatt ID, Rawal RS. Assessment of antioxidant properties in fruits of *Myrica esculenta*: A popular wild edible species in Indian Himalayan Region. *Evid. Based Complement. Altern*. 2011; 2011: 1–8.

[197] Mezadri T, Villano D, Fernandez-Pachon MS, Garcia-Parrilla MC, Troncoso AM. Antioxidant compounds and antioxidant activity in acerola (*Malpighia emarginata* DC.) fruits and derivatives. *J. Food Compos. Anal*. 2008; 21: 282–290.

[198] Esfahlan A, Jamei R. Properties of biological activity of ten wild almond (*Prunus amygdalus* L.) species. *Turk. J. Biol*. 2012; 36: 201–209.

[199] Bunea A, Rugina DO, Pintea AM, Sconta Z, Bunea CI, Socaciu C. Comparative polyphenolic content and antioxidant activities of some wild and cultivated blueberries from Romania. *Not. Bot. Horti Agrobot. Cluj-Napoca*. 2011; 39: 70–76.

[200] Bhuiyan MAR, Hoque MZ, Hossain SJ. Free Radical Scavenging Activities of *Zizyphus mauritiana*. *World J. Agric. Sci*. 2009; 5(3): 318–322.

[201] Lamien-Meda A, Lamien CE, Compaore MMY, Meda RNT, Kiendrebeogo M, Zeba B, Millogo JF, Nacoulma OG. Polyphenol content and antioxidant activity of fourteen wild edible fruits from Burkina Faso. *Molecules* 2008; 13: 581–594.

[202] Murillo E, Britton GB, Durant AA. Antioxidant activity and polyphenol content in cultivated and wild edible fruits grown in Panama. *J. Pharm. Bioallied Sci*. 2012; 4: 313–317.

[203] Luximon-Ramma A, Bahorun T, Crozier A. Antioxidant actions and phenolic and vitamin C contents of common Mauritian exotic fruits. *J. Sci. Food Agric*. 2003; 83: 496–502.

[204] Garzon GA, Narvaez CE, Riedl KM, Schwartz SJ. Chemical composition, anthocyanins, non-anthocyanin phenolics and antioxidant activity of wild bilberry (*Vaccinium meridionale* Swartz) from Colombia. *Food Chem*. 2010; 122: 980–986.

[205] Devi YR, Mazumder PB. *In vitro* antioxidant activity of ethanol and aqueous extracts of *Eugenia operculata* Roxb. *J. Pharm. Biol. Sci.* 2013; 8: 95–100.

[206] Butkhup L, Samappito S. Changes in physico-chemical properties, polyphenol compounds and antiradical activity during development and ripening of Maoluang (*Antidesma bunius* L . Spreng) fruits. *J. Fruit Ornam. Plant Res*. 2011; 19(1): 85–99.

[207] Samappito S, Butkhup L. Analysis of anthocyanin, flavonoids, and phenolic acids in tropical Bignay berries. *Int. J. Fruit Sci*. 2008; 8: 15–34.

[208] Jorjong S, Butkhup L, Samappito S. Phytochemicals and antioxidant capacities of Mao-Luang (*Antidesma bunius* L.) cultivars from Northeastern Thailand. *Food Chem*. 2015; 181: 248–255.

[209] Nkafamiya II, Ardo BP, Osemeahon SA, Akinterinwa A. Evaluation of nutritional, non-nutritional, elemental content and amino acid profile of *Azanza garckeana* (Goron Tula). *Br. J. Applied Sci. Technol*. 2016; 12(6): 1–10.

[210] Huang WY, Cai YZ, Corke H, Sun M. Survey of antioxidant capacity and nutritional quality of selected edible and medicinal fruit plants in Hong Kong. *J. Food Compos. Anal.* 2010; 23: 510–517.

[211] Onuegbu NC, Adedokun II, Kabuo NO. Nwosu JN. Amino acid profile and micronutrient composition of the Africa pear (*Dacryodes edulis*) pulp. *Pak. J. Nutr*. 2011; 10: 555–557.

[212] Njoku NE, Ubbaonu CN, Alagbaoso SO, Eluchie CN, Umelo MC. Amino acid profile and oxidizable vitamin content of *Synsepalum dulcificum* berry (miracle fruit) pulp. *Food Sci. Nutr*. 2015; 3(3): 252–256.

[213] Kossah R, Nsabimana C, Zhao J, Chen H, Tian F, Zhang H, Chen W. Comparative study on the chemical composition of Syrian sumac (*Rhus coriaria* L.) and Chinese sumac (*Rhus typhina* L.) fruits. *Pak. J. Nutr*. 2009; 8(10): 1570–1574.

[214] Cheng JY, Ye XQ, Chen JC, Liu DH, Zhou SH. Nutritional composition of underutilized bayberry (*Myrica rubra*) kernels. *Food Chem*. 2008; 107: 1674–1680.

[215] Magaia TLJ, Skog K. Composition of amino acids, fatty acids and dietary fibre monomers in kernels of *Adansonia digitata* and *Sclerocarya birrea*. *Afr. J. Food Agric. Nutr. Dev*. 2017; 17(3): 12441–12454.

[216] Mariem C, Sameh M, Nadhem S, Soumaya Z, Najiba Z, Raoudha EG. Antioxidant and antimicrobial properties of the extracts from *Nitraria retusa* fruits and their applications to meat product preservation. *Ind. Crops Prod*. 2014; 55: 295–303.

[217] Ozcelik B, Koca U, Kaya D, Sekeroglu N. Evaluation of the *in vitro* bioactivities of mahaleb cherry (*Prunus mahaleb* L.). *Romanian Biotech. Lett*. 2012; 17: 7863–7872.

[218] Anand SP, Deborah S, G Velmurugan. Antimicrobial activity, nutritional profile and phytochemical screening of wild edible fruit of *Catunaregam spinosa* (Thunb.) Tirveng. *The Pharma Innovation* 2017; 6(10): 106–109.

[219] Saklani S, Chandra S. *In vitro* antimicrobial activity, nutritional profile and phytochemical screening of wild edible fruit of Garhwal Himalaya (*Ficus auriculata*). *Int. J. Pharm. Tech. Res.* 2012; 12(2): 61–64.

[220] Hassan LEA, Sirat HM, Yagi SMA, Koko WS, Abdelwahab SI. *In vitro* antimicrobial activities of chloroformic, hexane and ethanolic extracts of *Citrullus lanatus* var. *citroides* (wild melon). *J. Med. Plants Res*. 2011; 5: 1338–1344.

[221] Pio-Leon JF, Diaz-Camacho SP, Lopez-Lopez MA, Uribe-Beltran MD, Willms K, Lopez-Angulo G, Montes-Avila J, Delgado-Vargas F. Antibacterial activity of extracts obtained from the nanchi (*Byrsonima crassifolia* (L.) Kunth), arrayan (*Psidium sartorianum* (O. Berg) Nied.) and ayale (*Crescentia alata* Kunth) fruits. *Bol. Latinoam*. *Caribe Plantas Med*. 2013; 12: 356–364.

[222] Radovanovic BC, Andelkovic ASM, Radovanovic AB, Andelkovic MZ. Antioxidant and antimicrobial activity of polyphenol extracts from wild berry fruits grown in Southeast Serbia. *Trop. J. Pharm. Res*. 2013; 12: 813–819.

[223] Saklani S, Chandra S, Mishra AP, Badoni PP. Nutritional evaluation, antimicrobial activity and phytochemical screening of wild edible fruit of *Myrica nagi* pulp. *Int. J. Pharm. Pharm. Sci*. 2012; 4: 407–411.

[224] Saklani S, Chandra S. *In vitro* antimicrobial activity, nutritional value, antinutritional value and phytochemical screening of *Pyracantha crenulata* fruit. *Int. J. Pharm. Sci. Rev. Res*. 2014; 26(1): 1–5.

[225] Hendra R, Ahmad S, Sukari A, Shukor MY, Oskoueian E. (2011) Flavonoid analysis and antimicrobial activity of various parts of *Phaleria macrocarpa* (Scheff.) Boerl fruit. *Int. J. Mol. Sci*. 2011; 12: 3422–3431.

[226] Njoku NE, Ubbaonu CN, Alagbaoso SO, Agunwa IM, Eluchie CN. Proximate, anti-nutritional and phytochemical composition of the yellow variety of the *Synsepalum Dulcificum* (Miracle fruit) berry. *American J. Food Sci. Tech*. 2016; 4: 102–108.

[227] Edem C A, Dosunmu MI. Chemical evaluation of proximate composition, ascorbic acid and anti-nutrients content of african star apple (*Chrysophyllum afrcanum*) fruit. *Int. J. Res. Rev. Appl. Sci.* 2011; 9(11): 146–149.

[228] Omidiran MO, Baiyewu RA, Ademola IT, Fakorede OC, Toyinbo EO, Adewumi OJ, Adekunle EA. Phytochemical analysis, nutritional composition and antimicrobial activities of white mulberry (*Morus alba*). *Pak. J. Nutr*. 2012. 11(5): 456–460.

[229] Mahadkar S, Valvi S, Rathod V. Screening of anti-nutritional factors from some wild edible plants. *J. Nat. Prod. Plant Resour*. 2012; 2: 251–255.

[230] Adepoju OT. Proximate composition and micronutrient potentials of three locally available wild fruits in Nigeria. *African J. Agric. Research* 2009; 4(9): 887–892.

[231] Umaru HA, Adamu R, Dahiru D, Nadro MS. Levels of anti-nutritional factors in some wild edible fruits of northern Nigeria. *Afr. J. Biotech*. 2007; 6: 1935–1938.

[232] Anhwange BA, Tyohemba RL, Tukura BW, Ogah P. Screening of some indigenous wild fruits for anti-nutritional factors. *J. Sci. Res. Rep.* 2015; 5(3): 220–227.

[233] Isfahlan AJ, Mahmoodzadeh A, Hassanzadeh A, Heidari R, Jamei R. Antioxidant and antiradical activities of phenolic extracts from Iranian almond (*Prunus amygdalus* L.) hulls and shells. *Turk. J. Biol*. 2010; 34: 165–173.

[234] Radovanovic BC, Andelkovic ASM, Radovanovic AB, Andelkovic MZ. Antioxidant and antimicrobial activity of polyphenol extracts from wild berry fruits grown in Southeast Serbia. *Trop. J. Pharm. Res*. 2013; 12: 813–819.

[235] Papandreou MA, Dimakopoulou A, Linardaki ZI, Cordopatis P, Klimis-Zacas D, Margarity M, Lamari FN. Effect of a polyphenol-rich wild blueberry extract on cognitive performance of mice, brain antioxidant markers and acetylcholinesterase activity. *Behav. Brain Res*. 2009; 198: 352–358.

[236] Egea I, Sanchez-Bel P, Romojaro F, Pretel MT. Six edible wild fruits as potential antioxidant additives or nutritional supplements. *Plant Food Hum. Nutr*. 2010; 65: 121–129.

[237] Ruiz-Rodriguez BM, de Ancos B, Sanchez-Moreno C, Fernandez-Ruiz V, Sanchez-Mata MD, Camara M, Tardio J. Wild blackthorn (*Prunus spinosa* L.) and hawthorn (*Crataegus monogyna* Jacq.) fruits as valuable sources of antioxidants. *Fruits* 2014; 69: 61–73.

[238] Sharma PB, Handique PJ, Devi HS. Antioxidant properties, physico-chemical characteristics and proximate composition of five wild fruits of Manipur, India. *J. Food Sci. Technol.* 2015; 52: 894–902.

[239] Kubota M, Ishikawa C, Sugiyama Y, Fukumoto S, Miyagi T, Kumazawa S. Anthocyanins from the fruits of *Rubus croceacanthus* and *Rubus sieboldii*, wild berry plants from Okinawa, Japan. *J. Food Compos. Anal*. 2012; 28: 179–182.

[240] Augusto TR, Salinas ESS, Alencar SM, D'Arce MABR, Camargo ACD, Vieira TMFD. Phenolic compounds and antioxidant activity of hydroalcoholic extracts of wild and cultivated murtilla (*Ugni molinae* Turcz.). *Food Sci. Technol*. 2014; 34: 667–679.

[241] Malta LG, Tessaro EP, Eberlin M, Pastore GM, Liu RH. Assessment of antioxidant and anti-proliferative activities and the identification of phenolic compounds of exotic Brazilian fruits. *Food Res. Int*. 2013; 53: 417–425.

[242] Omena CMB, Valentim IB, Guedes GD, Rabelo LA, Mano CM, Bechara EJH, Sawaya ACHF, Trevisan MTS, da Costa JG, Ferreira RCS. Antioxidant, anti-acetylcholinesterase and cytotoxic activities of ethanol extracts of peel, pulp and seeds of exotic Brazilian fruits. *Food Res. Int*. 2012; 49: 334–344.

[243] Chalise JP, Acharya K, Gurung N,Bhusal RP, Gurung R, Skalko-Basnet N, Basnet P. Antioxidant activity and polyphenol content in edible wild fruits from Nepal. *Int. J. Food Sci. Nutr*. 2010; 61: 425–432.

[244] Leontowicz H, Leontowicz M, Drzewiecki J, Haruenkit R, Poovarodom S, Park YS, Jung ST, Kang SG, Trakhtenberg S, Gorinstein S. Bioactive properties of snake fruit (*Salacca edulis* Reinw.) and mangosteen (*Garcinia mangostana*) and their influence on plasma lipid profile and antioxidant activity in rats fed cholesterol. *Eur. Food Res. Technol*. 2006; 223: 697–703.

[245] Santacruz L, Carriazo JG, Almanza O, Osorio C. Anthocyanin composition of wild Colombian fruits and antioxidant capacity measurement by electron paramagnetic resonance spectroscopy. *J. Agric. Food Chem*. 2012; 60: 1397–1404.

[246] Ruiz-Rodriguez BM, Sanchez-Moreno C, de Ancos B, Sanchez-Mata MD, Fernandez-Ruiz V, Camara M, Tardio J. Wild *Arbutus unedo* L. and *Rubus ulmifolius* Schott fruits are underutilized sources of valuable bioactive compounds with antioxidant capacity. *Fruits* 2014; 69: 435–448.

[247] Oszmianski J, Nowicka P, Teleszko M, Wojdylo A, Cebulak T, Oklejewicz K. Analysis of phenolic compounds and antioxidant activity in wild blackberry fruits. *Int. J. Mol. Sci*. 2015; 16: 14540–14553.

[248] Fazio A, Plastina P, Meijerink J, Witkamp RW, Gabriele B. Comparative analyses of seeds of wild fruits of *Rubus* and *Sambucus* species from Southern Italy: Fatty acid composition of the oil, total phenolic content, antioxidant and anti-inflammatory properties of the methanolic extracts. *Food Chem*. 2013; 140: 817–824.

[249] De Assis S, Vellosa JCR, Brunetti IL, Khalil NM, Leite KMDC, Martins ABG, Oliveira OMMD. Antioxidant activity, ascorbic acid and total phenol of exotic fruits occurring in Brazil. *Int. J. Food Sci. Nutr*. 2009; 60: 439–448.

[250] Contreras-Calderon J, Calderon-Jaimes L, Guerra-Hernandez E, Garcia-Villanova B. Antioxidant capacity, phenolic content and vitamin C in pulp, peel and seed from 24 exotic fruits from Colombia. *Food Res. Int*. 2011; 44: 2047–2053.

[251] Sasipriya G, Maria CL, Siddhuraju P. Influence of pressure cooking on antioxidant activity of wild (*Ensete superbum*) and commercial banana (*Musa paradisiaca* var. Monthan) unripe fruit and flower. *J. Food Sci. Technol.* 2014; 51: 2517–2525.

[252] Banerjee A, Dasgupta N, De B. *In vitro* study of antioxidant activity of *Syzygium cumini* fruit. *Food Chem*. 2005; 90: 727–733.

[253] Netzel M, Netzel G, Tian QG, Schwartz S, Konczak I. Native Australian fruits - a novel source of antioxidants for food. *Innov. Food Sci. Emerg. Technol*. 2007; 8: 339–346.

[254] Almeida MMB, de Sousa PHM, Arriaga AMC, do Prado GM, Magalhaes CEDC, Maia GA, de Lemos TLG. Bioactive compounds and antioxidant activity of fresh exotic fruits from northeastern Brazil. *Food Res. Int.* 2011; 44: 2155–2159.

[255] Mao AA, Hyniewta TM, Sanjappa M. Plant wealth of Northeast India with reference to ethnobotany. *Ind. J. Tradit. Knowl*. 2009; 8(1): 96–103.