CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Thai underutilized fruit and vegetable species as a potential sources of antioxidants, minerals and vitamins: a literature review

BACHELOR'S THESIS

Prague 2021

Author: **Kateřina Berková**

Supervisor: Ing. Johana Rondevaldová, Ph.D.

Declaration

I hereby declare that I have done this thesis entitled Thai underutilized fruit and vegetable species as a potential sources of antioxidants, minerals and vitamins: a literature review independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 15th April 2021

....

Kateřina Berková

Acknowledgements

I would like to express my great thanks to Ing. Johana Rondevaldová Ph.D. for her professional guidance, patience, and thoughtful advice and suggestions. I would also like to thank my family and Miss Terezie Baitlová, who were a great support to me.

Abstract

At present, when humanity is still facing persistent malnutrition, diseases of affluence such as non-communicable diseases are emerging at the same time. The main reason is general malnutrition or insufficient consumption of fruits and vegetables. These are irreplaceable sources of many biologically active substances such as antioxidants that protect body cells against oxidative damage caused by free radicals, minerals that play a huge role in various biological processes such as transmitting nerve impulses or building strong bones, and vitamins that serve as antioxidants, coenzymes, cofactors, hormones, and gene transcription elements. Deficiencies of these substances can be fatal in the long run. Often ignored sources of these substances are underutilized crops which have many benefits such as high nutritional value, resistance to biotic stresses, and ability to strengthen the food security of the country. Thailand is a part of Indo-Burma Biodiversity Hotspot, one of the most biodiverse areas in the world, and provides various kinds of fruits and vegetables, including little-explored species. Also, Thai cuisine is rich in local unique ingredients and considered healthy. The aim of this thesis was to identify Thai underutilized fruit and vegetable species showing interesting antioxidant activity and containing notable amounts of minerals and vitamins. In this thesis, 73 underutilized species of Thai fruits and vegetables were found in the scientific literature. Some of them show significant contents of antioxidants, minerals, and vitamins. The most promising crops in the terms of antioxidants seem to be *Durio kutejensis* and *Cosmos caudatus*, in the terms of minerals *Neptunia oleracea* and *Dracontomelon dao*, and in the terms of vitamins, *Aegle marmelos*, *Mangifera odorata*, and *Sesbania grandiflora*. Some species including for example *A. marmelos* or *S. grandiflora* showed valuable contents of all 3 monitored parameters and therefore it would be appropriate to promote them more to locals as they could enrich their diet and increase their financial incomes and standard of living. Also, such species could be used in industry and for the production of various food products such as beverages, desserts, or even food supplements. For 8 species, no data on antioxidant activity and contents of minerals and vitamins were available and it would be therefore appropriate to focus on their research as they may have nutritional potential.

Keywords: edible plants, human nutrition, neglected crops, Southeast Asia, unexploited plant species

Abstrakt

V současnosti, kdy lidstvo čelí přetrvávajícímu hladu, se zároveň projevují takzvané civilizační choroby, jako jsou například nepřenosné choroby. Hlavním důvodem je buď celková podvýživa, nebo nedostatečná konzumace ovoce a zeleniny. Ta je nenahraditelným zdrojem biologicky aktivních látek, jako jsou antioxidanty chránící buňky před oxidačním poškozením volnými radikály, minerály hrající důležitou roli v mnoha biologických procesech, ať už se jedná o přenos nervových vzruchů nebo budování kostí a vitaminy, které slouží jako antioxidanty, koenzymy, kofaktory, hormony a genové transkripční prvky. Nedostatky těchto látek mohou být v dlouhodobém měřítku fatální. Často přehlíženými zdroji těchto látek jsou málo známé a podceňované plodiny, které disponují mnoha benefity, jako je například jejich vysoká nutriční hodnota, rezistence vůči biotickým stresům nebo schopnost posílit potravinovou bezpečnost země. Thajsko je součástí Indo-Barmského Biodiverzitního Hotspotu, což je jedna z nejvíce biologicky rozmanitých oblastí světa a poskytuje nepřeberné množství různých druhů ovoce a zeleniny, včetně málo prozkoumaných druhů. Navíc je thajská kuchyně bohatá na jedinečné místní ingredience a je považována za zdravou. Cílem této práce bylo identifikovat málo známé a podceňované druhy ovoce a zeleniny se zajímavou antioxidační aktivitou a obsahem hodnotného množství minerálů a vitaminů. V této práci bylo z odborné literatury identifikováno celkem 73 těchto druhů ovoce a zeleniny pocházejících z Thajska. Mezi nutričně nejslibnější patří z hlediska antioxidantů *Durio kutejensis* a *Cosmos caudatus*, z hlediska minerálů *Neptunia oleracea* a *Dracontomelon dao* a z hlediska vitaminů *Aegle marmelos*, *Mangifera odorata* a *Sesbania grandiflora*. Některé druhy jako například *Aegle marmelos* nebo *Sesbania grandiflora* vykazují hodnoty u všech 3 sledovaných parametrů, a proto by bylo dobré je více propagovat místním obyvatelům, protože by mohly obohatit jejich jídelníček, zvýšit finanční příjmy a úroveň života. Zároveň by také mohly být zajímavé pro průmysl a výrobu různých potravin, ať už se jedná o nápoje, dezerty nebo potravinové doplňky. U 8 druhů nebyla nalezena žádná data ohledně obsahu antioxidantů, minerálů a vitaminů, a proto by bylo vhodné zaměřit se na jejich výzkum, protože mohou mít nutriční potenciál.

Klíčová slova: jedlé rostliny, jihovýchodní Asie, nedostatečně využívané plodiny, neprozkoumané druhy rostlin, výživa člověka

Contents

List of figures

List of tables

List of the abbreviations used in the thesis

$^{\bullet}O_2^{-}$, $O_2^{\bullet -}$	superoxide radical
$^{\bullet}OH$	hydroxyl radical
$^{1}O_2$	singlet oxygen
AAE	ascorbic acid equivalent
ABTS	2,2′-azinobis (3-ethylbenothiazoline-6-sulfonic acid) diammonium salt
ADP	adenosine diphosphate
AEAC	ascorbic acid equivalent antioxidant capacity
Al	aluminium
ALB	albumin
As	arsenic
ATP	adenosine triphosphate
B	boron
B_1	thiamine
B_2	riboflavin
B_3	niacin
B_4	adenine
B_5	pantothenic acid
B_6	pyridoxine
B_7	biotin
B_8	inositol
B_9	folic acid, folate
B_{10}	para-aminobenzoic acid
B_{11}	choline
B_{12}	cyanocobalamin
BHAE	t-butylated hydroxyanisole equivalent
BIL	bilirubin
C3G	cyanidin-3-glucoside equivalent
Ca	calcium
CAT	catalase
CCE	cyanidin chloride equivalent

Cd	cadmium
CE	catechin equivalent
CKD_S	chronic kidney diseases
Cl	chlorine
Co	cobalt
$CO_3^{\bullet-}$	carbonate radical
CoA	coenzyme A
CoQ	coenzyme Q
CP	ceruloplasmin
Cr	chromium
Cu	copper
CUPRAC	modified cupric reducing antioxidant capacity
CVD_S	cardiovascular diseases
DNA	deoxyribonucleotide acid
DPPH	2,2-diphenyl-1-picryl-hydrazyl-hydrate
dw	dry weight basis
E	east
EC_{50}	half maximal effective concentration
EDTAE	ethylenediaminetetraacetic acid equivalent
F	fluoride
FAD	flavin adenine dinucleotide
FAO	Food and Agriculture Organization of the United Nations
Fe	iron
FER	ferritin
FRAP	ferric reducing antioxidant power
fw	fresh weight basis
GAE	gallic acid equivalent
GP_X	glutathione peroxidase
GSH	glutathione
GSSG	oxidized glutathione
H_2O_2	hydrogen peroxide
Hg	mercury
I	iodine

IARC	International Agency for Research on Cancer
IC_{50}	half maximal inhibitory concentration
IU	International Unit
K	potassium
LA	alpha-lipoic acid
$LO^{\bullet}$	alkoxyl radical derived from fatty acids
$LOO^{\bullet}$	peroxyl radical derived from fatty acids
LTF	lactoferrin
MB	myoglobin
MBP_S	metal binding proteins
MD_S	macular diseases
Mg	magnesium
Mn	manganese
Mo	molybdenum
MT_S	metallothioneins
Na	sodium
NAD	nicotinamide adenine dinucleotide
NADP	nicotinamide adenine dinucleotide phosphate
ND_S	neurodegenerative diseases
Ni	nickel
$NO^{\bullet}$	nitric oxide radical
O_3	ozone
$ONOO^-$	peroxynitrite
ORAC	oxygen radical absorbance capacity
P	phosphorus
PABA	para-aminobenzoic acid
PROSEA	Plant Resources of South-East Asia
PUFA	polyunsaturated fatty acids
QE	quercetin equivalent
RDA	recommended dietary allowance
RE	rutin equivalent
RNA	ribonucleotide acid
RNS	reactive nitrogen species

$RO^{\bullet}$	alkoxyl radical
$ROO^{\bullet}$	peroxyl radical
ROS	reactive oxygen species
S	sulphur
S[t]	south
Se	selenium
SE	southeast
Si	silicon
Sn	tin
SOD	superoxide dismutase
TAE	tannic acid equivalent
TE	trolox equivalent
TEAC	trolox equivalent antioxidant activity
TF	transferrin
UL	Tolerable Upper Intake Level
UV	ultraviolet radiation
V	vanadium
WHO	World Health Organization
Zn	zinc

1. Introduction

One of the most discussed challenges currently facing humanity is how to secure access to sufficient, healthy, nutritious, and affordable food which is produced in a sustainable manner. Although the number of people suffering from hunger has halved since the early days of the Green Revolution, humanity is still facing situations in which populations are poorly nourished. In 2017 the number of undernourished people reached 821 million, which indicates a rise in world hunger after a prolonged decline. However, hunger is not the only problem in human nutrition. In addition to the problem of lack of key minerals in 2 billion people, more than 672 million adults worldwide are obese, and 151 million children are affected by stunting. A principal cause of the multiple malnutrition burdens is poor diet. Current food systems produce large quantities of food, which is, however, poor in nutrients and include insufficient amounts of plant-based product needed for healthier and sustainable diets. At the same time, modern agriculture practices and food production systems make a significant contributor to major environmental issues. This includes especially ecosystems pollution, land degradation, contamination and shortages of water, greenhouse gas emissions, and biodiversity loss (Hunter et al. 2019). Fruits and vegetables are the keys to tackling malnutrition. For the people of developing countries, fruits and vegetables are an irreplaceable source of essential substances such as antioxidants, minerals, and vitamins and often also the only source of food. For the people of developed countries who often live a comfortable modern way of life and consume processed foods full of empty calories, fruits and vegetables represent a source of essential micronutrients and moreover dietary food that is advisable to consume daily (FAO 1995; Hall et al. 2009; Pem & Jeewon 2015). Thailand is a country with significant plant biodiversity where many kinds of fruits and vegetables are widely grown, processed, and exported. Even so, almost unknown species can still be found in Thailand. Such species, which are called underutilized or neglected, are interesting in terms of micronutrient content. Underutilized species have the potential to contribute to food security due to often significant nutritional values. Furthermore, such species have the ability to strengthen the food and buffer economy of the country, and also the ability to increase the biodiversity of cultivated crops and thus contribute to the sustainability of agriculture (Padulosi et al. 2013).

2. Aims of the Thesis

The aim of this thesis was to identify underutilized fruit and vegetable species originating in Thailand and to describe their importance as a source of micronutrients, specifically antioxidants, minerals, and vitamins. The partial aims of the thesis were to describe the importance of fruits and vegetables in human nutrition, to point out the diseases associated with deficiencies and surpluses of the mentioned micronutrients, and to summarize available data on Thai underutilized fruit and vegetable species in a clear table with contained antioxidants, minerals, and vitamins.

3. Methodology

A literature review was performed by using professional scientific databases such as ResearchGate, ScienceDirect, PubMed, and Web of Knowledge and relevant bibliographies, journals, and textbooks. Individual species were selected on basis of available publications concerning their nutritional value. The keywords used in the search were especially 'micronutrient content', 'antioxidant activity', and 'Thai origin'. The correctness of the plant names was verified using The Plant List database. Obtained data on the nutritional values of species were summarized in the table. In this thesis, citations were created according to the Conservation Biology citation style.

4. Literature Review

4.1. Fruits and vegetables in human nutrition

There are no single precise meanings for the terms *fruits* and *vegetables*. Various classifications based on the chemical composition, botanic families, colours, or edible parts have been designed, but the scientists have not accepted a universal classification system. According to health experts, the definitions heavily vary due to food selection and preparation, which is affected by cultural norms and customs all over the world. Differences occur even within a particular country, where the consumers use different categories when classifying species. A clear example is a potato, which belongs to the group of starches rather than to the group of vegetables, or legumes, which may be categorized by vegetarians primarily as proteins and not vegetables. Low agreement within and across various institutions has led to significant differences in guidance and recommendations. For example, World Cancer Research Foundation excluded potatoes and other starches to increase vegetable intake, while Australia or the United States include potatoes as a vegetable (Thompson et al. 2011). In 2003, International Agency for Research on Cancer (IARC) published a Fruit and Vegetables IARC Handbook of Cancer Prevention, where the species of various fruits and vegetables are systematically defined and classified according to botanical differences, culinary differences, and cultural differences in culinary definitions. Botanical term *fruit* relates to the ripe ovary of the plant, seeds, and all adjacent tissues, without any consideration of whether these are edible or not. The food-related botanical term for *fruit* is an edible part of the plant that includes seeds and surrounding tissues. This includes dry fruits with papery, woody, or leathery ovaries such as pulses, nuts, or grains and fleshy fruit such as cantaloupe, tomatoes, blueberries, or peach. Botanical term *vegetables* in the broad concept include trees, bushes, vines, and vascular plants, edible or not. As related to the food, there are 2 botanical definitions. First, a vegetable is an edible part of the plant such as roots, stems, stalks, tubers, bulbs, leaves, flowers, fruits, and seeds. Second, a vegetable is a plant grown for its edible parts. From a culinary point of view, there are 5 major groups of plant foods: fruits, vegetables, nuts, seeds, and cereal grains. People use this system to communicate about various plant-based foods and to distinguish between them. Culinary groupings are widely used in households, education settings, marketplaces, and restaurants. The culinary term *fruit* is used for edible parts of plants that have a sweet or tart taste and contain seeds and surrounding pulpy tissue. Fruits are usually consumed as a dessert, or in the form of juices, syrups, jams, etc. The culinary term *vegetable* refers to edible parts of a plant such as roots, tubers, stems, stalks, bulbs, leaves, flowers, pulses, fruits, fungi, algae, sweet corn, and some cereal grains. Culinary nuts and fruits are not included in the group of vegetables, but the distinctions often depend on the flavour they provide and on cultural customs. These distinctions tend to be imprecise and vary within and between cultures. Information about which species serve as fruits and vegetables is found in cookbooks or food guides published by professional nutritional institutions and relevant government agencies. Although there are countless classification systems of fruits and vegetables for the dietary assessment, these are most helpful if based on the composition of these species (Vainio & Bianchini 2003; Pennington & Fisher 2009).

Fruits and vegetables, along with nuts, are of great importance in human nutrition because of the essential substances they provide. Mainly, these are sources of vitamins, minerals, dietary fiber, and other useful chemicals. Carbohydrates, fats, and proteins contents of species play a significant role in the tropical and subtropical regions because fruits and vegetables are often the only source of food and thus have not only the role of supplementing the necessary vitamins, minerals, and other chemical components, but also a role of satiating. Examples are found especially in the group of roots and tubers. For the people of the developing world, crops such as sweet potatoes, taro, yams, and cassava account for roughly 40 % of the food eaten. In the Indochinese-Indonesian region, fruits and vegetables staple foods include primarily bamboo, banana, coconut, grapefruit, mango, and yam. Also, some vegetable species are very important and only guaranteed safe source of water during the whole year. In addition to the mentioned nutrients, fruits and vegetables also provide many other useful substances and materials. This includes textile fibres, fuels, building materials, oils, essential substances, and natural remedies. Fruit species often provide vegetables in the form of shoots or leaves. Consumption of sufficient amounts of fruits and vegetables is associated with a reduced risk of chronic diseases. Despite the growing focus of their health benefits, consumption is below recommended intake in adults. Low fruit and vegetable intake is a global problem and leads to millions of deaths each year. This is an obstacle especially in developing countries, where people suffer from a total lack of food (FAO 1995; Valíček 2002; Hall et al. 2009; Pem & Jeewon 2015).

Since ancient times, fruits and vegetables were a part of the human diet, but until recently, many exotic species were unknown in Europe. It changed at the beginning of the 20th century when technical progress in maritime and air transport made it possible to import into Europe perishable species such as mango and avocado. Tropical and subtropical areas, including Thailand, offer a much larger range of species than the temperate areas. Some of them are one of the most important cultivated plants, while others are part of natural plant communities. A large percentage of these crops are imported to other parts of the world, where there are surpluses, while the supply of fruits and vegetables to the people of developing countries is completely inadequate (Valíček 2002). Measured by quantity, the most produced fruits in the world are bananas, watermelons, apples, oranges, grapes, and mangoes. Vegetable production is dominated by tomatoes, onions, cucumbers and gherkins, cabbages and other brassicas, eggplants, and carrots (Shanbandeh 2021[a]; Shanbandeh 2021[b]). The world-leading producers of fruits and vegetables are China, followed by India, Brazil, United States, Turkey, and Iran (European Fresh Produce Association 2015). In 2018, the total production of primary crops increased to 9.1 billion tonnes, which is 2.9 billion tonnes more than in 2000. The main crops grown were cereals and sugar crops with a total of 33 %, respectively 24 %. Vegetables accounted for 12 % of total production and fruit accounted for 9 to 11 %, which is the same as oil crops, roots, and tubers. High crop production was associated with many factors, among which the use of irrigation, fertilizers, pesticides, high-yield crops, improved farming practices, and the size of the cultivated area had the greatest impact (FAO 2020[a]). The growing demand for new fruit and vegetable species in developed countries has led to the flourishing of small farms and created many rural and urban jobs in developing countries. Local people can invest in the purchase of valuable commodities such as meat, fruits, and vegetables, thanks to extra incomes from the production of demanded species (FAO 2003).

Insufficient intake of fruits and vegetables is inextricably linked to the development of diseases of affluence, also known as Western diseases or lifestyle diseases. It mainly concerns the developed countries of the Western world, where there is a surplus of food and people can choose from a wide range of products. High meat and calorie availability together with sedentary jobs, overuse of alcohol and tobacco products, bad psychosocial relationships, influences of pollutants in the environment, or influences of new technologies on humans cause the spread of diseases of affluence. It has been documented that in upper-middle-income and high-income countries, the worst situation is in the lowest classes of society. In terms of nutrition, the consumption of processed foods plays the biggest role. A larger and larger proportion of a consumer's diet is represented by foodstuffs such as sweetened beverages and snacks, fast food, pasta, or frozen prepared meals. Besides, cheap ingredients such as processed sugar, fats, and salts are used in these foods to maintain demand and save costs. As a result, the consumer receives a large portion of empty calories without adequate amounts of proteins, high-quality fats, fiber, vitamins, and minerals. It is very worrying that this type of meal, also known as "the American diet", is becoming an important component of the diet, especially in city dwellers. Moreover, in Europe and North America, the prevalence of high calories income has led to increased rates of obesity. However, obesity is not the only disease of affluence. The most common diseases of affluence include:

- Malnutrition diseases (obesity, anorexia, bulimia, stomach ulcers)
- Cardiovascular diseases (CVDs) such as atherosclerosis or hypertension
- Diabetes mellitus
- High cholesterol
- Neurodegenerative diseases (NDs)
- Macular diseases (MDs)
- Chronic kidney diseases (CKDs)
- Oncological diseases
- Atopic eczema and allergies
- Autoimmune diseases (rheumatoid arthritis)
- Musculoskeletal system diseases (back pain)
- Addictions
- Burnout syndrome and fatigue syndrome

(Ezzati et al. 2005; Česká průmyslová zdravotní pojišťovna 2021; InTeGrate 2018; Al-Gubory & Laher, 2017).

These non-communicable diseases cause more deaths every year than any other cause of death. It has been shown that 31 % of coronary heart disease and 11 % of stroke worldwide are associated with low consumption of fruits and vegetables. These clearly speaking data were the impetus for the World Health Organization (WHO) and Food and

Agriculture Organization of the United Nations (FAO), who set the recommended intake of fruits and vegetables on at least 400 grams per day (excluding starchy crops). The optimal amount of course depends on age, sex, physical activity, and many other factors. The recommended intake of 400 grams can be also replaced by 5 servings of 80 grams each. Intake of such an amount should prevent the spread of diseases of affluence and alleviate several microelements deficiencies, especially in developing countries (FAO & WHO 2004). The year 2021 has been declared as International Year of Fruits and Vegetables by the United Nations to emphasize the nutritional and health benefits of fruits and vegetables consumption. The aim of this project is to raise awareness of a balanced, varied diet, healthy lifestyle, and the need to reduce waste and loss of these highly perishable crops (FAO 2020[b]).

The chemical composition of fruit and vegetable species varies according to the level of maturity prior to harvest, the condition of ripeness, which develops after harvest and is affected by storage conditions, and also according to the botanical variety of species, weather, and cultivation practices. Even though we have completely different fruit and vegetable species, we can generalize the basics that apply to most of them. In general, fruits and vegetables are low in fat and protein and high in water, which is vital in many physiological processes. Fresh fruits and vegetables contain more than 70 % of water and frequently more than 85 %. Usually, the fat content is not more than 0.5 % and the protein content is not more than 3.5 %. The exceptions are legumes, which are a rich source of protein, and some species of vegetables such as avocado or sweer corn, which are higher in fat. Both fruits and vegetables are important sources of carbohydrates. Digestible carbohydrates are present in the form of starches and sugars and indigestible in the form of cellulose, which is important for normal digestion. In summary, the composition consists mainly of water and primary metabolites, but from a nutritional point of view, secondary metabolites and other biologically active substances are much more important in fruits and vegetables (Dauthy 1995).

Similar to other agricultural products, fruits and vegetables are prone to pollution and spoilage, which affect the health of consumers. Undesirable substances and organisms occur either naturally or through human intervention. The sources of pollution and thus various toxic substances are mainly soil, acidic rainwater, polluted irrigation water, sewage, oil pollution, wastes, pesticide residues, and microbial organisms such as bacteria, fungi, and other parasites. Especially irrigation with unrefined sanitary drainage water is a problem due to the accumulation of heavy metals in the soil and cultivated crops. It is known that the consumption of food polluted by heavy metals such as cadmium, chromium, copper, lead, and mercury has harmful effects on human health. Metal poisoning symptoms include divagation among adults, mental retardation among children, disturbances of the central nervous system, insomnia, liver and kidney diseases, emotional instability, and depression (Khashroom et al. 2019).

4.1.1. Primary metabolites

Fruits and vegetables contain most of the essential components of human nutrition. Their nutrient composition is very complex and difficult to assess. Plant metabolites are chemical substances that determine the nutritional value of fruits and vegetables. Levels of plant metabolites are highly affected by environmental and genetic factors, and also by transportation and storage conditions. Changes in the composition of metabolites are induced by growth factors such as temperature, humidity, light, soil type, use of fertilizers and pesticides, the action of microorganisms and insects, UV radiation, and heavy metals (Hounsome et al. 2008).

Plant primary metabolites are essential chemical substances involved in growth, development, photosynthesis, respiration, and protein and hormone synthesis and are found in all species within various phylogenetic groups. These include for example amino acids, carbohydrates, and fatty acids. In some cases, substances such as organic acids or alcohol are considered primary metabolites (Hounsome et al. 2008).

From the human nutritional point of view, the most common classification of primary metabolites is into the groups of carbohydrates, lipids, and proteins. These are required to provide energy, growth, maintenance, and repair of tissues (Singh et al. 2017).

Formed in the process of photosynthesis, **carbohydrates** are one of the major constituents of plants and represent the largest proportion of organic compounds. Carbohydrates are needed for a healthy and balanced diet and functions in many physiological processes, such as providing sources of energy (40–80 % of total energy intake), forming part of structural components, defensive measures to prevent the tissues from drying out, etc (Tharanathan et al. 1987). Carbohydrates are stable organic molecules containing carbon, hydrogen, and oxygen. In almost all cases they are derived from plant-based foods (except lactose). In human nutrition, carbohydrates are classified into 3 main groups: sugars, oligosaccharides, and polysaccharides. Sugars are the simplest forms of carbohydrates and include monosaccharides (glucose, fructose, galactose), disaccharides (sucrose, lactose, maltose, trehalose), and sugar alcohols (sorbitol, mannitol, lactitol, xylitol, erythritol, isomalt, maltitol). Oligosaccharides are chemical compounds in which units of monosaccharides are linked by glycosidic bonds. Oligosaccharides are divided into malto-oligosaccharides, also known as α-glucans (maltodextrins), and non-α-glucans (raffinose, stachyose, fructo-oligosaccharides, galacto-oligosaccharides, inulin, polydextrose). Polysaccharides are the most complex carbohydrates. They are categorized into starches (amylose, amylopectin, modified starches) and non-starch polysaccharides (cellulose, hemicellulose, pectin, arabinoxylans, β-glucan, glucomannans, gums and mucilages, hydrocolloids). Carbohydrates are commonly found in fruits, vegetables, honey, cereals, yeasts, fungi, and lactose is found in milk (Cummings & Stephen 2007; Lunn & Buttriss 2007).

Fatty acids are chemical compounds that play several key roles human in metabolism. Fatty acids are involved in the storage and transport of energy, functioning of all membranes, and gene regulation. As a part of **lipids**, fatty acids also function in electrical and thermal insulation and mechanical protection. Moreover, polyunsaturated fatty acids (PUFA) are precursors for some locally acting metabolites (e.g. eicosanoids). They are classified into 2 main groups: saturated fatty acids (saturated with hydrogen) and unsaturated fatty acids (containing carbon–carbon double bond in the chain). Based on the length of the chain, fatty acids can be classified into short-chain (2–4 carbon atoms), medium-chain (6–10 carbons), and long-chain fatty acids (12–26 carbon atoms). The most common fatty acids include palmitic acid (saturated), stearic acid (saturated), myristic acid (saturated), oleic acid (unsaturated), palmitoleic acid (unsaturated), linoleic acid (unsaturated), arachidonic acid (unsaturated), α-linolenic acid (unsaturated), eicosapentaenoic acid (unsaturated), and docosahexaenoic acid (unsaturated). Fatty acids represent 30–35 % of total energy intake. Dietary sources are especially vegetable oils, grains, dairy products, meat, fatty fish, and fish oils (Rustan & Drevon 2005; Siram et al. 2019).

Plants are rich sources of amino acids, which are constituents of **proteins**. They function in many biological processes and in the transport and storage of all the nutrients including carbohydrates, proteins, fats, vitamins, minerals, and water. Also, amino acids have antioxidant effects on the human body and free amino acids are involved in secondary plant metabolism and biosynthesis of compounds such as glucosinolates and phenolics. Amino acids are categorized as essential (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine) and non-essential (alanine, asparagine, aspartic acid, cysteine, glutamic acid, glutamine, glycine, proline, serine, tyrosine) according to whether the human body can synthesize them or not. Other amino acids such as selenocysteine and pyrrolysine can also be found in the literature. Non-essential amino acids are synthesized by both humans and plants, but essential amino acids are synthesized only by plants and need to be supplemented through diet (Kumar et al. 2017[a]; Lopez & Mohiuddin 2021). Plant-based foods rich in amino acids are soybeans, chickpeas, microalgae, pea, lupin, sorghum, canola, corn germs, wheat flour, barley, rice, and potatoes (Petrusán et al. 2016).

4.1.2. Secondary metabolites

Secondary metabolites, also known as phytochemicals, are chemical compounds that are not vital for the organism but play a significant role in the interaction with its environment. They are often involved in protection against biotic (bacteria, fungi, insects, nematodes) and abiotic (high moisture, high temperature, injury, presence of heavy metals, shading) stresses. Some of the secondary metabolites have a great economic value thanks to their use as drugs, flavours, fragrances, dyes, and insecticides. Secondary metabolites are low molecular weight substances and their formation is generally organ, tissue, and cell-specific (Pagare et al. 2015). They have been shown to possess many biological effects, such as antiviral, antibiotic, and antifungal. Moreover, secondary metabolites can absorb UV radiation and thus protect the leaves from damage. It was noticed that some plants (alfalfa, clover) can even express estrogenic properties and affect the fertility of animals due to secondary metabolites (Hussein & El-Anssary 2019). The main classification system includes 3 major groups: alkaloids, phenolics, and terpenoids (Kabera et al. 2014).

Alkaloids are nitrogen atoms containing secondary metabolites. They are produced mostly by plants, but also by bacteria, fungi, and animals. Most of them are toxic to other organisms. Alkaloids are synthesized from amino acids. Compared to other secondary metabolites, there is great structural diversity, but no uniform classification system. Alkaloids include phytochemicals of various functions, for example, atropine (antibacterial/viral, anticholinergic, and antidiabetic effects), berberine (effects on cardiovascular system, anticancer effects), nicotine (stimulant, antiherbivore, insecticide, anti-inflammatory effects), and many others (Kabera et al. 2014).

Phenolics are secondary metabolites with certain health benefits such as antioxidant, anti-inflammatory, and anti-carcinogenic effects. They are found in almost all plants. Phenolics are usually present in hydroxylated aromatic rings and most of them are polymerized into larger compounds such as tannins or lignans. Phenolics are further classified according to 1) the number of hydroxylic groups, 2) the chemical composition, and 3) the substitutes in the carbon skeleton. Examples of phenolics are flavonoids, tannins, glycosides, or saponins (Kabera et al. 2014).

Terpenoids are polymeric isoprene derivates synthesized from acetate. Many terpenoids have pharmacological activity and serve for the treatment of various diseases. They have antiviral and antimicrobial properties and are most abundant in plants of the Laminaceae family. Terpenoids are also often used in industry as spices, flavours, and fragrances. The group of terpenoids includes for example carotenoids, gibberellic acid, and steroids (Kabera et al. 2014).

4.1.3. Antioxidants and their function in human nutrition

Antioxidants are natural or human-made chemical substances that may prevent or delay cell damage caused by Reactive Oxygen Species (ROS) and Reactive Nitrogen Species (RNS) and subsequently prevent the origin of the oxidative stress. Antioxidants are widely present in fruits, vegetables, and herbs, which were already the main sources of antioxidants for ancient people to protect their bodies against oxidative damage. It was proved that biologically active substances such as antioxidants have a great impact on human health, life expectancy, aging, and the evolution of many pathogens as well (Yadav et al. 2016). Their beneficial function lies in the ability to neutralize reactive forms of oxygen or nitrogen. These reactive forms are produced commonly during metabolism and the human body regulates their quantity through endogenous antioxidant systems. Systems regulating the amount of ROS and RNS can be enzymatic (superoxide dismutase, catalase) or non-enzymatic (ascorbic acid, glutathione). However, if the amount of ROS increases and exceeds the quantity which are endogenous antioxidant systems able to degrade, it can cause changes in cell structure and function. These changes have a positive impact on human health if the ROS are produced physiologically. Beneficial functions of ROS are the entry of sperm into the egg (ROS produced by sperm), killing parasites and bacteria (ROS produced by macrophages), killing tumor cells (ROS produced by T-cells), or bone remodeling (ROS produced by osteoclasts). Unfortunately, in most cases, the impact of ROS is highly negative (Stratil & Kubáň 2018). The harmful effects of ROS when their production increases above basal level are especially pathological conditions ranging from autoimmune diseases to cardiomyopathies (Patel et al. 2018).

ROS, in other words, free radicals, are signalling molecules to regulate biological and physiological processes. Although high concentrations of ROS and RNS lead to cell death, lower concentrations can cause changes in the activity of transcriptional factors. ROS also play a significant role in cell differentiation and proliferation. Imbalance in the rate of ROS production cause damages to many biomolecules such as nucleic acids, proteins, and lipids (Pleńkowska et al. 2020). Biologically important radicals include:

- **Hydroxyl radical** ($^{\bullet}OH$) which is one of the most reactive ever. It is mostly generated in cells by Fenton's reaction, where transition metal ions react with hydrogen peroxide (H_2O_2), but can also arise from respiratory chain, ozone decomposition, or homolytic cleavage of H_2O_2. Hydroxyl radical causes neurological, aging-related or chronic diseases by damage of structure and function of biomolecules such as nucleic acids, heterolipids, and triacylglyceroles (Lipinski 2011; Cadet et al. 2012).
- **Carbonate radical** ($CO_3^{\bullet -}$) is a major endogenous one-electron oxidant that has a larger range of action than short-lived hydroxyl radicals. These radicals are formed by a reaction of hydroxyl radical with carbonate ions (for example abstraction of a hydrogen atom from bicarbonate by a hydroxyl radical). $CO_3^{\bullet -}$ is a dangerous oxidant due to its longer lifetime and far-reaching action compared with hydroxyl radical. $CO_3^{\bullet -}$ causes damages to important biomolecules including proteins and nucleic acids (Cadet et al. 2012; Hardeland 2017).

  $CO_3^{2-} + {}^{\bullet}OH \rightarrow \mathbf{CO_3^{\bullet -}} + OH^-$

$HCO_3^- + {}^{\bullet}OH \rightarrow \mathbf{CO_3^{\bullet-}} + H_2O^-$

- **Superoxide radical** (${}^{\bullet}O_2^-$ or $O_2^{\bullet-}$) is an anion radical produced by one-electron reduction of molecular oxygen (O_2). $O_2^{\bullet-}$ is primarily produced by phagocytes and neutrophils to kill bacteria. Superoxide radicals can react with other biomolecules and free radicals and can form a diverse array of additional ROS and RNS. Many biomolecules are sensitive to superoxide radical because it can react in several ways and can produce highly reactive ${}^{\bullet}OH$ (Cadet et al. 2012; Al-Gubory & Laher, 2017; Kehrer & Klotz 2015; Stratil & Kubáň 2018).
- **Peroxyl and alkoxyl radicals** ($ROO^{\bullet}$ and $RO^{\bullet}$ or $LOO^{\bullet}$ and $LO^{\bullet}$ if derived from fatty acids). Peroxyl radicals are formed by the reaction of molecular oxygen with carbon-centred radicals, and they are far more stable than alkoxyl radicals or carbon-centred radicals. Alkoxyl radicals are intermediate in reactivity between peroxyl radicals and hydroxyl radicals. These radicals cause oxidation of adenine, guanine, cytosine, thymine, and also react with lipids, carbohydrates, and proteins and cause their damage (Simandan et al. 1998; Kehrer & Klotz 2015).
- **Nitric oxide radical** ($NO^{\bullet}$), in other words, nitrosyl radical, is a highly reactive free radical, has the ability to easily cross through biomembranes, and is one of the most important regulating molecules in a living cell. Nitrosyl radicals represent the major cause of the damage of biomolecules by triggering a chain reaction of free radicals or by direct destruction. $NO^{\bullet}$ has the ability to inhibit enzymes (cytochrome oxidase, ribonucleotide reductase), to release iron from proteins, to affect the activity of enzymes hem-binding iron, to modify gene expression, and to inhibit DNA replication (Slezák et al. 2016; Stratil & Kubáň 2018).

Biologically important non-radicals include:

- **Peroxynitrite** ($ONOO^-$) is a strong oxidizing agent exhibiting a wide array of tissue-damaging effects, including inactivation of enzymes and ion channels via protein oxidation and nitration, lipid peroxidation, and inhibition of mitochondrial respiration (Zaja-Milatovic & Gupta 2020).

- **Hydrogen peroxide** (H_2O_2) is a relevant member of the ROS family. It was proven that superoxide radical present in human cells willingly converts into H_2O_2. High concentrations of hydrogen peroxide lead to cell injury by damaging key cellular molecules such as lipids and DNA. These injuries can even lead to genome instability, carcinogenesis, and cell death (Gough & Cotter 2011).
- **Singlet oxygen** ($^1O_2$). Molecular oxygen is a very strong oxidant agent if contained in the electronic singlet state. Singlet oxygen is considered as one of the most responsible ROS for producing oxidative stress in organisms. Harmful effects of $^1O_2$ are damage of nucleic acids, oxidizing of membrane lipids, or causing dysfunction of sarcoplasmic reticulum (Alia et al. 2001; DeFedericis et al. 2006; Stratil & Kubáň 2018).
- **Ozone** (O_3) is a triatomic gas with a typical smell that irritates eyes and lungs and is poorly soluble in water. Ozone is formed by dissociation of O_2 molecule by type C ultraviolet radiation (UV) in the atmosphere into oxygen atom which reacts with O_2. Ozone is a strong oxidizing agent, easily binds to fatty acids and forms ozonide which decomposes into toxic substances such as $^{\bullet}OH$. Ozone is also a pulmonary irritant and causes inflammation and injury of lung tissue (Valavanidis et al. 2013; Stratil & Kubáň 2018).

A state where increased generation of ROS overwhelms antioxidant protection is called oxidative stress. In the normal healthy state, oxidation occurs naturally in cells. However, if there is an imbalance between oxidants and antioxidants, it potentially leads to damage. During the past three decades, it was proved that oxidative stress is associated with prenatal and postnatal developmental disorders. These disorders originate mainly in undernutrition, malnutrition, unhealthy lifestyle behaviours, and exposure to chemical pollution. Oxidative stress together with cellular senescence are involved in several acute chronic pathological processes such as NDs, CKDs, MDs, cancer, CVDs, and other diseases of affluence (Sies 2000; Al-Gubory & Laher 2017; Liguory et al. 2018).

In Western countries, the human diet is often associated with the consumption of red meat and dairy products, but not with the consumption of a sufficient quantity of fruits and vegetables that contain the necessary antioxidants, minerals, vitamins, and other useful chemical components. Without them, the body is exposed to excessive ROS production, which results in oxidative stress and may potentially contribute to the emergence of diseases of affluence. These pose a great risk to all developed countries. It is assumed that with the development of the economy, diseases such as CVDs and their nutritional risk factors including overweight, obesity, and elevated blood pressure also develop relentlessly (Ezzati et al. 2005; Al-Gubory & Laher 2017). As mentioned before, the most common diseases of affluence are, for example, hypertension, heart attack, coronary heart disease, sudden stroke, metabolic syndrome (Reaven´s syndrome), obesity, osteoporosis, cancer, allergy, chronic fatigue syndrome, depression, eating disorders, diabetes, varicose veins, appendicitis, diverticular disease, dental caries, Alzheimer´s disease and Parkinson´s disease (Uttara et al. 2009; Al-Gubory & Laher 2017).

Regular consumption of antioxidants containing species has been recognized as reducing the risk of chronic diseases. Well-known species containing antioxidants are blueberries, broccoli, citrus fruits, grapes, kale, plums, red beans, spinach, strawberries, and many others. Recent studies also suggested that lesser-known and exotic species such as *Artocarpus heterophyllus* Lam. (jackfruit), *Butia capitata* (Mart.) Becc. (pindo palm), and *Cereus jamacaru* DC. (mandacaru cactus) are great sources of antioxidants (Yadav et al. 2016). Widely discussed is also *Euterpe oleracea* Mart. (acai berry) from Brazil, which contains one of the largest amounts of antioxidants such as polyphenols or anthocyanins (Costa et al. 2013).

Organisms including plants, animals, and humans have naturally a complex of multiple types of antioxidants present in their bodies, such as vitamin C, vitamin E, enzyme catalase (CAT), or superoxide dismutase (SOD). In this thesis, I decided to introduce very widely used divisions of antioxidant groups, which can be found in many scientific journals such as ScienceDirect or PubMed. We can divide them into different groups: based on the type of their source there are natural and synthetic antioxidants, based on their solubility there are water-soluble and lipid-soluble antioxidants and we can also categorize natural antioxidants into enzymatic and non-enzymatic (Mamta et al. 2014). Antioxidant protection strategies may involve these mechanisms:

- Catalytic removal of reactive particles (SOD, CAT)
- Control of reactive particle formation (transferrin, albumin, oxygenase)

- Protection of biomolecules against oxidative damage (PUFA enzymes)
- Physical quenching of reactive particles (carotenoids)
- Replacement of oxidation-sensitive molecules with resistant ones (fumarase)
- Adding a substrate that easily reacts with the reactive particles to prevent damage of important biomolecules (ascorbate, urate, α-tocopherol)
- Adding a substrate that reacts with the reactive particle to form cytoprotective product (nitro-fatty acids)
- The spatial divide of reactive species (glutathione-S-transferase)
(Mamta et al. 2014; Stratil & Kubáň 2018).

Natural antioxidants are synthesized in the human body through the metabolic system or can be supplemented from a natural source. We can sort natural antioxidants into two major groups, enzymatic and non-enzymatic (Mamta et al. 2014; Atta et al. 2017).

Enzymatic antioxidants primarily include SOD, CAT, and GPx (glutathione peroxidase). These provide stability or inactivation of free radicals before they attack cellular biomolecules. Enzymatic antioxidants are therefore essential for maintaining cellular and systemic health (Mamta et al. 2014; Atta et al. 2017).

Superoxide dismutase is an antioxidant that reduces highly reactive superoxide radical ($^{\bullet}O_2^-$) to form less reactive hydrogen peroxide (H_2O_2) and oxygen (O_2). In the human body, we can find three forms of SOD, cytosolic Cu/Zn-SOD, mitochondrial Mn-SOD, and extracellular SOD. Natural sources of SOD are broccoli, cabbage, wheatgrass, or Brussel sprouts (Atta et al. 2017).

$^{\bullet}O_2^- + ^{\bullet}O_2^- + 2\ H^+ \rightarrow H_2O_2 + O_2$

Catalase is an enzyme antioxidant that is responsible for the decomposition of hydrogen peroxide (H_2O_2) into water and oxygen. We can find CAT in the blood and most of the living cells (Mamta et al. 2014; Atta et al. 2017).

$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

Glutathione peroxidase protects the cell from damage due to hydrogen and lipid peroxides. The human body contains two types of GPx, cellular and plasma GPx. This enzymatic antioxidant catalyses the reaction of hydrogen peroxide with glutathione (GSH) to form oxidized glutathione (GSSG) (Mamta et al. 2014; Atta et al. 2017).

$H_2O_2 + 2\ GSH \rightarrow 2\ H_2O + GSSG$

Non-enzymatic antioxidants include nutrient-derived antioxidants (ascorbic acid, carotenoids, glutathione, tocopherols), metal-binding proteins (albumin, ferritin), and many others. Non-enzymatic antioxidants are divided into endogenous and exogenous, which are present in commonly consumed species of fruits, vegetables, nuts, and cereal products (Mirończuk-Chodakowska et al. 2018).

Metal-binding proteins (MBPs) are endogenous non-enzymatic antioxidants with the ability to bind metal ions. Thanks to this feature they can bind extremely pro-oxidant ions (Cu^{2+}, Fe^{2+}) that would otherwise enter the Fenton´s reaction and would catalyze ROS formation. MBPs include antioxidants **ferritin** (FER), **myoglobin** (MB), **albumin** (ALB), **ceruloplasmin** (CP), **metallothioneins** (MTs), **transferrin** (TF), and **lactoferrin** (LTF) (Mirończuk-Chodakowska et al. 2018).

Other endogenous antioxidants include **glutathione** (GSH), **alpha-lipoic acid** (LA), **coenzyme Q** (CoQ), **uric acid**, **methionine**, **bilirubin** (BIL), and polyamines such as **putrescine**, **spermidine,** and **spermine** (Aguilar et al. 2016; Moussa et al. 2020).

Nutrient-derived antioxidants are supplied to the human body through diet. These include vitamins, minerals, polyphenols, carotenoids, flavonoids, and others (Mamta et al. 2014). According to Bouayed & Bohn (2010), principal exogenous dietary antioxidants are:

- **Vitamin C** and **vitamin E**
- Trace elements (**zinc**, **selenium**)
- Carotenoids (**lutein**, **β-carotene**, **lycopene**, **zeaxanthin**)
- Phenolic acids (**gallic acid**, **chlorogenic acid**, **caffeic acid**)
- Flavonols (**myricetin**, **quercetin**, **kaempferol**, and their glucosides) *
- Flavanols (**catechins** and **proanthocyanidins**) *
- Anthocyanidins (**pelargonidin**, **cyanidin,** and their glucosides) *
- Isoflavones (**glycitein**, **genistein**, **daidzein** and their glucosides) *

- Flavanones (**eriodictyol**, **hesperetin**, **naringenin,** and their glucosides) *
- Flavones (**apigenin**, **luteolin,** and their glucosides) *

* belongs to the group of flavonoids

These and many other antioxidants are extremely important in defence against oxidative damage. It is necessary for human health to include species containing these chemical substances in the diet (Halliwell et al. 1995).

Like almost everything in our world, also antioxidants have a dark side called pro-oxidant activity. Antioxidants consumed as supplements may have a negative impact on human health. This fact is known in the medical community, but not among the population, who often believe in the non-toxicity of these natural products. Problems are rooted in the long-term excessive income of antioxidants containing supplements. These can result for example in birth defects among babies (vitamin A), an increase of HDL cholesterol (vitamin A), risk of kidney stones (vitamin C), rise in CVDs mortality in postmenopausal women with diabetes (vitamin C), or prostate cancer risk (vitamin E) (Salehi et al. 2018).

4.1.4. Minerals and their function in human nutrition

Minerals are inorganic substances belonging to a group of micronutrients, as well as vitamins. Although the human body needs very small amounts of minerals to function properly, most of the minerals are essential for humans and form an integral part of the diet. Minerals play an important role in countless biochemical processes, whether it is transmitting nerve impulses or building strong bones. Minerals also take part in hormone synthesis and functioning and can regulate standard heartbeat and some of them are part of teeth and bones structure. The main source of micronutrients for humans are plants, but some of the micronutrients are present only in low quantities and deficiencies may occur when there is insufficient income. At the 1990 World Summit for Children, deficiencies of 2 microminerals (iron, iodine) and 1 micronutrient (vitamin A) were identified as predominantly common and posing a risk to public health in developing countries. In 2019 WHO added multiple micronutrient powder to a list of essential medicines due to widespread shortage. Prevention of deficiency occurrence lies in the consumption of varied diets containing sufficient amounts of required minerals (Gharibzahedi & Jafari 2017; Awuchi et al. 2020).

Minerals are divided into two major groups: macrominerals (macroelements, major minerals) and microminerals (trace elements, microelements), depending on how much the body needs. Macrominerals are those needed in higher amounts than 100 mg per day, while microminerals are needed in amounts lower than 100 mg per day. Macrominerals include calcium (Ca), chloride (Cl), magnesium (Mg), phosphorus (P) potassium (K), sodium (Na), and sulphur (S). These are present in the body in large amounts ranging from hundreds of milligrams to grams. Members of microminerals are boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluoride (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn). Amounts of microminerals are measured in micrograms. Compared to microminerals, macrominerals are largely involved in transmission and signalling in nerve cells and in blood pressure control. On the contrary, microminerals play key roles in erythrocyte formation, glucose level regulation, and activation of antioxidant enzymes (Lecos 1983; European Food Safety Authority 2006; Gharibzahedi & Jafari 2017).

Macrominerals

Calcium is a macromineral important for healthy teeth and bones, involved in nerve functioning, muscle contraction and relaxation, immune system functioning, blood pressure regulation, and blood clotting. Good sources are dairy products, canned fish with bones (sardines, salmon), tofu, green leafy vegetables, broccoli, nuts, thyme, mustard greens, and dill. The Recommended Dietary Allowance (RDA) is set at 1,200 mg per day, The Tolerable Upper Intake Level (UL) is set at 2,500 mg per day. Deficiency is manifested by hypocalcaemia (numbness of fingers, carpal spasms, muscle cramps, and others) (Murphy & Williams 2009; Gharibzahedi & Jafari 2017; Awuchi et al. 2020). Signs of excessed income (hypercalcaemia) are vomiting, polyuria, dehydration, and renal impairment (Evans 1986).

Chlorine is a part of all body secretions and excretions resulting from processes of anabolism and catabolism of body tissues. Chlorine is found in plasma membranes of erythrocytes and in hydrochloric acid in the stomach. Chlorine is also involved in the regulation of osmotic pressure and electrolyte balance. The main dietary source is table salt, but some amounts are also found in seaweed, rye, celery, olives, tomatoes, and animal products. RDA is set at 2,300 mg per day and UL is set at 3,600 mg per day.

Amounts of the chlorine closely parallel amounts of sodium input and output since both of these macrominerals are part of sodium chloride (Britannica 2011; Gharibzahedi & Jafari 2017; Awuchi et al. 2020). Body supplies of chlorine are quickly depleted in hot weather when the fluid content of the body is reduced. Also, chlorine supplies may become low with persistent vomiting and diarrhoea, or during diseases causing alkalosis (Britannica 2011). Chlorine deficiency in humans is rare and occurs predominantly in infants because breast milk is poor in chlorine. In infants, chlorine deficiency is manifested by lethargy, irritability, growth failure, anorexia, or weakness. Chlorine deficiency may occur also in children and adults who consumed chloride-deficient liquid nutritional products. Chlorine excess due to dietary intake is uncommon and may occur during conditions associated with abnormal water losses. However, long-term increased income of sodium chloride is associated with elevated blood pressure and risk of CVDs (Turck et al. 2019), as mentioned before.

Magnesium is an element found in bones and is necessary for protein synthesis, muscle contraction, nerve transmission, proper functioning of the immune system, and also helps to avoid constipation. Magnesium-rich sources are spinach, legumes, seeds, nuts, artichokes, dairy products, and seafood. RDA is set at 250 to 350 mg per day, UL is set at 350 mg per day. Deficiency of Mg (hypomagnesemia) is manifested by muscle cramps, neuromuscular irritability with convulsions, and abnormal heartbeat. Hypermagnesemia may occur with excessive income of magnesium salts and causes diarrhoea, but it is rare in people with normal kidney function (WHO 2009; Gharibzahedi & Jafari 2017; Awuchi et al. 2020).

Phosphorus is a mineral found in every cell of the human body. Phosphorus is a component of phospholipids in biomembranes, nucleic acids, and nucleotides. Further, phosphorus participates in the maintenance of normal pH, transfer and storage of energy in the form of adenosine triphosphate (ATP), and activation of enzymes by the process of phosphorylation. Phosphorus is also needed for healthy teeth and bones and together with vitamins of B-complex supports kidney performance, regular heartbeat, nerve signalling, and muscle contraction (Gharibzahedi & Jafari 2017; Combet & Buckton 2019). Rich sources include pumpkin and squash seeds, Brazil nuts, rice, oats, legumes, and animal products such as poultry, fish, and red meat. RDA is set at 700 mg per day and UL is set at 4,000 mg per day (Gharibzahedi & Jafari 2017; Awuchi et al. 2020). Deficiency (hypophosphataemia) leads to cellular dysfunction and may occur in various diseases. These include anaemia, anorexia, bone pain, muscle weakness, debility, paraesthesia, ataxia, confusion, and the development of infections. Hyperphosphataemia (excessed phosphorus) may occur in response to increased absorption of phosphorus in the gastrointestinal tract, increased endogenous load, and decreased urinary excretion. Hyperphosphataemia manifests in reduced levels of magnesium and calcium in the body, which is dangerous for CKD_S patients in whom soft tissue calcification occurs (Weisinger & Bellorín-Font 1998).

In the human body, **potassium** is involved in the regulation of osmotic pressure and as it is a major electrolyte in the body, potassium also controls electrolyte balance. Further participates in the functioning of cardiovascular, endocrine, renal, digestive, and respiratory systems, in the metabolism of energy, and cell growth and division. Sources rich in potassium are potatoes, sweet potatoes, tomatoes, lentils, beans, plums, bananas, seafood, and dairy products. RDA is set at 4,700 mg per day. Deficiency is called hypokalaemia (serum potassium below 2.6 mmol/l), which occurs during starvation and in people with anorexia nervosa (Combet & Buckton 2019; Awuchi et al. 2020). Long-term low dietary intake manifests in increased blood pressure level, which is associated with the risk of CVD_S, particularly stroke (Bazzano et al. 2001). On the other hand, scientific studies have shown that potassium intake higher than 4,700 mg per day blunts the effect of increased sodium intake on blood pressure level (Rodrigues et al. 2014). Excessive intake, reduced renal excretion, or leakage of potassium from intercellular space can cause hyperkalemia (serum potassium exceeds 5.5 mmol/l). Hyperkalemia is a life-threatening condition, where muscular and cardiac dysfunctions appear (Lehnhardt & Kemper 2011).

Sodium is a necessary macromineral needed for the maintenance of electrolyte and fluid balance, and also in the heart function, nerve transition, and muscle contraction. Moreover, sodium together with potassium is involved in ATP regulation. The main source of sodium is table salt (NaCl, sodium chloride), milk, pickles, spinach, and sea vegetables. RDA is set at 1,500 mg per day and UL is set at 2,300 mg per day (Gharibzahedi & Jafari 2017; Awuchi et al. 2020). Deficiency is not diet-related and occurs only due to clinical conditions, especially during major trauma. Hyponatraemia (serum sodium concentration below 135 mmol/l) is one of the most common diseases observed in hospitalized patients. Symptoms of hyponatraemia are headache, loss of appetite, nausea, weakness, muscle cramps, disorientation, and personality changes. Hyponatraemia is often associated with seizures, prolonged hospitalization, and increased mortality (Somasundaram et al. 2014, Combet & Buckton 2019). The opposite problem is the excessive salt intake, which is the cause of raised blood pressure and leads to CVD_S. Excessive salt intake is also associated with the risk of obesity due to increased consumption of sugar-containing beverages (Ma et al. 2015).

Sulphur is one of the most abundant macrominerals in our body. Sulphur intake is provided by the diet, mainly from proteins. There are only 2 amino acids (cysteine and methionine) that contain sulphur and are commonly present in proteins. As a component of many proteins, sulphur functions in the protection against toxic substances, participates in the development of connective tissues, participates in the metabolism of energy as a part of the electron transport chain, and helps skin to maintain its integrity. Moreover, sulphur-containing amino acids are a part of the cellular antioxidant system. Sulphur is found in animal products (meat, poultry, eggs, fish, milk) and small amounts of sulphur in the form of inorganic sulphates are present in cruciferous vegetables (broccoli, kohlrabi, cauliflower) and allium vegetables (garlic, onion, chives) (Nimni et al. 2007; Gharibzahedi & Jafari 2017; Colovic et al. 2018). There is no RDA because sulphur is commonly found in foods. Deficiency threatens only in extreme protein deprivation. Toxicity may occur due to excessive intake of amino acid supplements and manifests in depressed growth (Marcus 2013).

Microminerals

Boron is a micromineral that helps with the processing of other minerals, e.g. phosphorus or magnesium, and maintaining the function of biomembranes. In the human body, boron improves levels of estrogen, which is needed for healthy bones and mental performance, especially in post-menopausal women and healthy men. Further, boron is involved in embryonic development and helps eliminate yeasts producing vaginal infections. Food sources of boron include potatoes, broccoli, carrots, apples, avocados, bananas, dried prunes, raisins, peaches, olives, almonds, hazelnuts, peanuts, legumes, honey, and even bee pollen (Gharibzahedi & Jafari 2017). There is no RDA for boron, but acceptable safe range intake is 1 to 13 mg per day for adults. UL is set at 20 mg per day for adults. Deficiency symptoms are not sufficiently described, but it is suggested that reduced mental alertness due to boron deficiency might affect brain function. In addition, consumption of a boron-poor diet leads to elevate urinary magnesium and calcium excretion and reduction in estrogen level in post-menopausal women. There are no available data on the effects of excess boron intakes from the diet or water. As some household cleaning products contain boron, toxicity symptoms are associated with accidental consumption, especially in children. Toxicity manifestations are nausea, intestinal discomfort, diarrhoea, vomiting, rash, convulsion, depression, and vascular collapse. Extremely high boron doses of 15,000 to 20,000 mg can be even fatal (US Office of Dietary Supplements 2020).

Chromium is an essential microelement involved in fats, nucleic acids, and carbohydrate metabolism. Chromium functions in the synthesis of fatty acids and cholesterol and is needed in the insulin regulation of glucose blood level. Commonly available sources are apples, bananas, green peppers, spinach, wheat germs, whole grains, nuts, black pepper, and molasses. Animal sources include beef, chicken, eggs, oysters, cheese, butter, and others (Gharibzahedi & Jafari 2017). RDA for chromium is set at 0.035 mg per day. The UL was not established, although a few adverse effects were associated with excess chromium intake from the diet. Poor chromium level is a factor contributing to impaired glucose tolerance and thus Type II diabetes. Chromium toxicity depends on the valence state. Hexavalent chromium shows the highest toxicity but is not found in food. Trivalent chromium, which is commonly present in the diet, has much lower toxicity levels and several studies have demonstrated the safety of high chromium III doses. Although, few cases of toxicity have occurred, including hepatic dysfunction, carcinogenicity, and skeletal muscle injury (US Institute of Medicine 2001).

Cobalt is an essential micromineral required for vitamin B_{12} synthesis. As bacteria are necessary for the synthesis of vitamin B_{12}, cobalt is considered part of this vitamin that comes from animal-based foods. Cobalt, in the form of vitamin B_{12}, is used to treat anaemia because of the promotion of erythrocyte formation. Also, cobalt helps with fatigue, neuromuscular and digestive disorders. Rich sources include organ meats, seafood, milk, oats, green leafy vegetables such as spinach, cabbage or lettuce, nuts, and shiitake mushrooms (Gharibzahedi & Jafari 2017; Awuchi et al. 2020). RDA and the UL are not precisely determined, but cobalt deficiency is closely related to vitamin B_{12} deficiency. Cobalt toxicity may occur in industry workers, not due to excessive dietary intake (Co is excreted in urine and does not accumulate in the body), but due to inhalation exposure to cobalt and other hard metal particles. Damage effects may lead to asthma or even lung cancer (Lison 2007).

Copper is another microelements group member contained in many enzymes, including cytochrome c oxidase (an enzyme involved in the mitochondrial respiratory chain). Copper is needed in the metabolism of proteins and iron, stimulates the immune system to act effectively against infections, and repairs damaged tissues. Further, copper is involved in neutralizing free radicals that cause serious cell damage. Food copper sources are legumes, cashew nuts, shiitake mushrooms, kale, whole grains, dried fruits, sesame seeds, avocados, and animal products such as organ meats, seafood, and goat cheese (Shoubridge 2001; Gharibzahedi & Jafari 2017). RDA for copper is set at 0.9 mg per day and UL is set at 5 to 10 mg per day (Awuchi et al. 2020). Current studies have shown that copper deficiency may be more prevalent than originally thought. A serious manifestation of deficiency is a genetic disorder called Menkes syndrome (degenerative disease of grey matter), while toxicity leads to Wilson disease (rare copper metabolism disorder that leads to copper accumulation in kidneys, nervous system, liver, and other organs) (El-Youssef 2008; De Romaña et al. 2011; Pascual & Menkes 2015).

Fluoride is another essential micromineral involved mainly in bone and teeth development and the prevention of teeth decay. Fluoridation (adding fluoride to tap water) helps with the reduction of cavities in children by more than half. Further, fluoride slows down the loss of bone density and maintains bone structure. The main sources of fluoride are seafood, deboned meat or chicken, naturally fluoride-containing or fluoridated drinking water, wine, beer, juice, and processed cereals (Gharibzahedi & Jafari 2017). RDA is set at 2 mg per day. Fluoride deficiency is associated with an increased risk of dental caries. Toxicity is the opposite problem. There are 3 types of toxic intake of fluoride (fluorosis): mottled teeth enamel, crippling fluorosis, and acute fluoride poisoning. Gross excessive exposure to fluoride manifests in nausea, vomiting, and seizures and may even escalate into coma and death. With the long-term intake of 20 to 80 mg per day, bone hypermineralization, bone growths, and ligament calcification occur (Cerklewski 1997).

Iodine is a component of thyroid hormones, which play a key role in many activities including growth, mental development, reproduction, metabolism, production of blood cells, functioning of nerves and muscles, and adjustment of body temperature. Further, iodine has antibiotic and anti-cancer effects and prevents goitre. Sources rich in iodine are bananas, dried plums, cranberries, seaweed, eggs, and iodized salt. RDA is set at 0.150 mg and UL is set at 0.6 to 1.5 mg per day for adults (Gharibzahedi & Jafari 2017; Combet & Buckton 2019; Awuchi et al. 2020). The deficiency of iodine is the most common cause of preventable mental impairment in the world. Deficiency also manifests in goitre, hypothyroidism (thyroid gland does not produce enough hormones), and in increased thyroid gland susceptibility to nuclear radiation. Iodine intakes up to 1,000 μg per day are well tolerated by adults, but in children, chronic intakes of 500 μg or more lead to increased thyroid volume, which is an early sign of dysfunction (Zimmermann et al. 2008).

Iron is needed in the human body for the synthesis of hemoglobin in red blood cells which carries oxygen throughout the body and for energy metabolism. Iron also functions as a medium for the transport of electrons in cells and participates in various enzymatic systems. Sources rich in iron are especially legumes, squash and pumpkin seeds, nuts, bran, whole grains, dark leafy vegetables, dried fruits, and animal products such as beef, lamb, poultry, and eggs (Gharibzahedi & Jafari 2017). RDA is set at 18 mg per day and UL is set at 45 mg per day for adults (Awuchi et al. 2020). Insufficient intake of iron causes iron deficiency anaemia and worsening of the immune response. Iron deficiency has also adverse effects on mental and psychomotor development in children (Combet & Buckton 2019). Contrary, high iron concentrations in tissues are associated with several pathological conditions, including cancer, heart and liver diseases, immune system dysfunctions, and hormonal abnormalities (Fraga 2002).

Manganese is a micromineral found in many enzymes, where it plays a role as a catalytic cofactor for arginase, SOD, and pyruvate carboxylase. Manganese is essential for normal brain functioning and nervous system activity. No less important function of manganese is the promotion of normal growth of human bone structure and prevention of osteoporosis. Good sources of manganese are hazelnuts, beans, pumpkin seeds, brewed black tea, cooked spinach, brown rice, seafood (especially mussels), fish, and tofu (Gharibzahedi & Jafari 2017; Combet & Buckton 2019). RDA is set at 2.3 mg per day and UL is set at 11 mg per day (Awuchi et al. 2020). Manganese deficiency is rare because it is widely available in various foods. However, experimental studies of manganese deficient diet consumption have reported symptoms of dermatitis, retarded growth of hair and nails, hair reddening, hypocholesterolemia, and decreased level of clotting proteins. Long-term exposure to high doses of manganese may lead to neurological disorders. This may occur especially in vegetarians, who consume large amounts of fruits and vegetables and thus manganese, which is abundant in them (Finley & Davis 1999; Combet & Buckton 2019).

Molybdenum plays a significant role in cell protection through the activation of enzymes involved in antioxidant processes in the blood. Molybdenum is also required for energy generation in cells involving macroelements. This micromineral is commonly present in chokeberry, legumes, spinach, Swiss chard, cucumber, whole grains, wheat flour, sunflower seeds, nuts, and in animal-origin foods (organ meats, eggs, milk) (Gharibzahedi & Jafari 2017). RDA is set at 0.045 mg per day and UL is set at 0.6 to 2 mg (Awuchi et al. 2020). There has never been observed nutritional deficiency induced by insufficient intake. Although molybdenum can be very toxic to animals, the potential toxicity in humans is low. Problems with excess occur in Armenia, where concentrations of molybdenum in soil are unusually high. Excessive molybdenum intake manifests in gout-like symptoms, joint ache, and elevated blood molybdenum. Acute toxicity (300-800 μg per day) results in seizures and hallucinations (Novotny & Peterson 2018).

Although **nickel** is essential for plants and bacteria, no biochemical functions have been demonstrated in humans and higher animals, so nickel is not essential for us. The highest concentrations of nickel are found in cocoa, almonds, hazelnuts, soya beans, oatmeal, and legumes. No RDA and UL have been established for a nickel. The intake of nickel from the average diet is estimated to be about 150 μg but may even reach 900 μg per day when consuming foods with high content. There have not been demonstrated deficiency signs in humans. Oral intake of 500 μg per day may aggravate hand eczema in sensitive individuals (European Food Safety Authority 2006).

Selenium is a micromineral that takes a part in the synthesis of antioxidant enzymes, which play a significant role in the protection against effects of heavy metals, free radicals, and other undesirable substances. Selenium is also involved in immune system stimulation, in the synthesis of the enzyme that activates the thyroid hormone, in detoxification processes, and in protection against various viruses (e.g. HIV). Selenium is found in green leafy vegetables (cabbage, spinach), various seeds (chia, sesame, sunflower), beans, brown rice, mushrooms, cooked oysters, beef, lamb, and tuna. (Gharibzahedi & Jafari 2017). RDA is set at 0.055 mg per day and UL is set at 0.3 to 0.4 mg per day (Awuchi et al. 2020). Selenium deficiency leads to Keshan’s disease, which is an endemic heart disease occurring in China and Russia and affecting mainly children and women of childbearing age (Thomson 2013). Selenium over-supplementation may result in selenosis. This disease manifests in brittle hair and nails, leading to a loss in some cases and breath and skin smelling of garlic. Symptoms of acute selenium poisoning are pulmonary edema and vomiting. Several cases occurred in the Chinese province of Hubei between 1961 and 1964 due to very high selenium content in soil (Fairweather-Tait et al. 2011).

Silicon is a mineral that has not been shown to be essential for humans. In the human body, silicon is found in connective tissues, including the aorta, trachea, tendon, bone, and skin, but the functional role has not yet been identified. Silicone is ingested by humans especially from grain products, various fruit and vegetable species, drinking water, coffee, and beer. Silicon is also added to foods as defoaming and anti-caking and agents. No RDA and UL have been established due to insufficient data. The average daily intake from the diet is approximately 20 to 50 mg of silicon. There is only a little evidence of the side effects of silicon, namely renal stones associated with long-term intake of silicate-containing antacids (European Food Safety Authority 2006).

Tin is not a nutritionally essential microelement for humans and has no known biological function. Tin is found in tinned fruits and vegetables, in multi-vitamin and mineral supplements, and also in bottled and canned white asparagus, where it is added as food additive E512. No RDA and UL have been established for tin and there is no data on deficiency effects resulting from insufficient intake. Long-term high doses lead to decreased absorption of zinc. Acute effects resulting from the consumption of tin contaminated foods manifest in abdominal pain, vomiting, diarrhoea, and headache (European Food Safety Authority 2006).

Vanadium is a microelement that has been shown not to be essential for humans. No biochemical function of vanadium has yet been identified in humans, but it has been considered that vanadium might play role in the metabolism of some enzymes, hormones, lipids, and glucose. Its role in the functioning of bones and teeth has also been discussed. The richest sources of vanadium include black pepper, dill seeds, whole grains, seafood, dairy products, and meat. No RDA has been established for vanadium. Recommended maximum level intake is 1.8 mg per day for adults. No signs of deficiency have been identified in humans. High oral doses of vanadium are associated with gastrointestinal disturbances such as abdominal cramps and diarrhoea (European Food Safety Authority 2006).

Zinc is a micromineral contained in many important enzymes, needed for the synthesis of protein and genetic material. Zinc has a main function in taste perception, increases smell perception, functions in wound healing, sperm production, fetal development, normal growth, immune system health, and sexual maturation. Good sources of zinc include wheat germs, leavened whole grains, pumpkin and squash seeds, cashew nuts, cocoa powder, spinach, cooked chickpeas, white mushrooms, beef and lamb meat, fish, and poultry (Gharibzahedi & Jafari 2017). RDA is set at 11 mg per day and UL is set at 25 to 40 mg per day for adults (Awuchi et al. 2020). Deficiency of zinc causes growth retardation, skeletal and sexual immaturity, neuropsychiatric diseases, alopecia, diarrhoea, dermatitis, loss of appetite, and greater infection susceptibility (Combet & Buckton 2019).

4.1.5. Vitamins and their function in human nutrition

Scientific studies at the beginning of the 20th century showed that there is some essential substance in milk for animal growth. Two factors were found to be essential. Factor A, which is fat-soluble and can be found in the cream, and factor B in the watery part of milk that is water-soluble. Factor B was identified as an amine and in 1913 the term vitamins began to be used for these vital amines. Vitamins are a group of various chemical substances with a variety of functions in the human body. What all the vitamins have in common is that they are organic substances essential for the maintenance of normal health and metabolic integrity. There are only two chemical compounds that are considered to be vitamins and can be synthetized in the human body: niacin, which is synthesized from the essential amino acid tryptophan, and vitamin D, which is synthesized from 7-dehydrocholesterol in the skin. In the human diet, vitamins are required in very small amounts, of the order of micrograms or milligrams per day (Bender 2009).

Vitamins serve in five general ways as antioxidants, gene transcription elements, donors or acceptors of H^+ and e^- (cofactors), hormones, and coenzymes. Systemically, vitamins are divided into two major classes, fat-soluble and water-soluble. Only a few of the vitamins are single substances. Most of them are families of chemically related substances called vitamers. The known vitamins are vitamin A, C, D, E, K and the group of B vitamins (B complex), which include thiamine (B_1), riboflavin (B_2), niacin (B_3), pantothenic acid (B_5), pyridoxine (B_6), biotin (B_7), folic acid (B_9, folate), and cyanocobalamin (B_{12}) (Combs 2012; Akram et al. 2020). In the case of adenine (vitamin B_4), inositol (vitamin B_8), para-aminobenzoic acid (PABA, vitamin B_{10}), and choline (vitamin B_{11}), the opinions of whether they are vitamins vary (Food Browser 2020). Therefore, they are mentioned only marginally in this thesis.

According to Combs (2012) and Akram et al. (2020), we can divide vitamins into five groups following their activity:

1) **Antioxidants**, including vitamin C (protects membrane phospholipids against oxidative stress) and vitamin E (protects cytosolic substances against oxidative stress).
2) **Gene transcription elements**, including vitamin A (binds to nuclear receptors), D (cooperates with nuclear receptor transcriptional factor), E (regulation of gene expression), vitamin C (supports cell differentiation), and some vitamins of the B complex (essential for methylation reactions) (Beckett et al. 2014).
3) **Hormones**, including vitamin A (coordination of metabolism responses) and vitamin D (coordination of metabolism responses in calcium homeostasis).
4) **Cofactors**, including vitamin C, vitamin K, niacin, riboflavin, and pantothenic acid. Cofactors are low-molecular-weight non-proteins, that are essential components of enzyme-catalysed reactions and are covalently bound to the enzyme (Chenault et al. 1988).
5) **Coenzymes**, including vitamin A, vitamin C, vitamin K, thiamine, niacin, riboflavin, pyridoxine, biotin, pantothenic acid, folic acid, and cyanocobalamin. Coenzymes, such as cofactors, are molecules that are used by enzymes to catalyse reactions. Coenzymes contain functionalities that are not found in proteins (Broderick 2001).

However, the most common systematic distribution of vitamins is water-soluble and fat-soluble. Water-soluble vitamins include vitamin C and B complex, while fat-soluble vitamins include vitamins A, D, E, and K (Akram et al. 2020).

Fat-soluble vitamins

Vitamin A refers to a group of fat-soluble substances with a biological activity called retinol (alcohol), retinal (aldehyde), retinoic acid (oxidized form of retinol), retinyl esters, and provitamins of vitamin A – carotenoids (especially β-carotene). The vital biological roles of vitamin A are cell differentiation, normal cell growth, vision, and immunology. Preformed vitamin A can be only taken from the diet of animal origin and it is the main source of vitamin A for humans. The provitamin A is consumed and then absorbed from plant-derived foods, primarily from oils, fruits, and vegetables (Fairulnizal Md Noh et al. 2019). RDA for men is 900 μg and for women 700 μg of retinol per day. UL for adults is 3,000 μg per day (US Institute of Medicine 2001). Vitamin A insufficiency leads to xerophthalmia, visual impairments, Bitot’s spots, anorexia, follicular hyperkeratosis, keratomalacia, growth retardation, degeneration of myelin sheaths, and intestinal and respiratory infections. Worldwide, 33.3 % of pre-school children suffer from vitamin A deficiency and 80,000 deaths occur due to vitamin A deficiency in Ethiopia every year. Good sources of vitamin A are animal products such as milk, egg yolk, meat, and fish oil. Sources of provitamin A are green leafy vegetables (broccoli, spinach), yellow vegetables (carrot, pumpkin), or lesser-known Brazilian fruit Buriti (*Mauritia flexuosa*), or Vietnamese fruit called Gac (*Momordica cochinchinensis*) (Akram et al. 2020). Conversely, excessive income is associated with the risk of osteoporosis and hip fracture, only with twice the amount of vitamin A UL (Penniston & Tanumihardjo 2006).

Vitamin D is a fat-soluble vitamin, which is contained in very few foods, especially in oily fish such as salmon or mackerel. Plant sources include mushrooms, cottonseed, lettuce, wheat, or clove basil (*Ocimum gratissimum*). It can be taken as a dietary supplement, but vitamin D is also produced endogenously (more precisely vitamin D_3). The synthesis is triggered when ultraviolet rays strike the skin. It means that the sunlight, especially UV-B radiation, is one of the most important sources for vitamin D_3 synthesis from 7-dehydrocholesterol, as mentioned before. In the human body, vitamin D is present in 2 forms: vitamin D_2 (also called ergocalciferol) which is of plant origin and vitamin D_3 (cholecalciferol) which is of animal origin. For humans, vitamin D is essential for the regulation of Ca in the body and for immune modulation. The deficiency of vitamin D is a pandemic problem with the major cause of lack of appreciation that the exposure to sunlight which is the major source of vitamin D for humans. In response to widespread vitamin D deficiency, fortifications of certain foods such as cheese, milk, or margarine are performed. Vitamin D deficiency results in rickets, osteoporosis, CVDs, diabetes, cancers, infections, osteopenia, and fractures in adults (Holick & Chen 2008; Omotosho 2019; Jan et al. 2019; Singh et al. 2020[a]). RDA of vitamin D varies mainly according to age. RDA for infants is 10 μg per day, for adults 20 μg per day, and for adults over 70 years 25 μg per day. UL of vitamin D is 25–100 μg per day in children and adolescents, 100 μg per day in adults, and 250 μg per day in the elderly. On the other hand, inappropriately long-term overdosing leads to hypercalciuria and hypercalcemia (Pludowski et al. 2018).

Vitamin E is a major fat-soluble antioxidant and plays an important role in the cell antioxidant system. Vitamin E protects cell membranes and low-density lipoproteins from oxidative stress (Böhm 2018). Term vitamin E is used for a group of tocopherols and tocotrienols, among which the α-tocopherol has the highest biological activity and is the most abundant form of vitamin E in nature. Humans and animals cannot synthesize this vitamin in the body, so supplementation through diet is necessary. Major sources of vitamin E are cereals, nuts, especially almonds, seeds, and vegetable oils. Intestinal absorption, same as transport by blood and cell uptake of vitamin E is possible only in the presence of lipid molecules (Rigotti 2007; Traber & Manor 2012). Other substances belonging to a group of vitamin E are β-, γ- and δ-tocopherols and α-, β-, γ- and δ-tocotrienols. For nutritional purposes, vitamin E content is usually expressed using alpha-tocopherol equivalents which are based on the activity of tocopherols and tocotrienols. These equivalents were defined as 1.0 mg α-tocopherol, 0.5 mg β-tocopherol, 0.1 mg γ-tocopherol, 0.03 mg δ-tocopherol, 0.3 mg α-tocotrienol and 0.05 mg β-tocotrienol. No biological activities of γ- and δ-tocotrienols were defined. Sufficient income of vitamin E prevents the generation of chronic diseases such as CVDs, atherosclerosis, and cancer. Vitamin E works as a chain-breaking antioxidant and prevents the propagation of free radicals. The deficiency leads to genetic diseases spinocerebellar ataxia and myopathy due to free radical damage to nerves (Brigelius-Flohé & Traber 1999; Cho 2010;

European Food Safety Authority 2015). RDA of vitamin E is 15 mg per day and for lactating women 19 mg per day. UL is 1,000 mg per day (Traber & Manor 2012). Overdose toxicity is low, even if the income is as high as 3,200 mg per day (Bendich & Machlin 1988).

Vitamin K is the last fat-soluble vitamin, which is responsible for blood homeostasis. Vitamin K has been found to prevent the development of chronic diseases such as CVDs, osteoarthritis, cognitive impairment, dementia, mobility disability, and frailty. There are 2 forms of vitamin K. Vitamin K_1 (phylloquinone) is present in green leafy vegetables (kale, broccoli, spinach, lettuce) or vegetable oils (soybean, sunflower, olive) and is the main source of vitamin K in the human diet. The second form is called vitamin K_2 (menaquinone), which can be found in animal-based diets or in fermented foods. Vitamin K_2 is also produced in the human gut by bacteria (Simes et al. 2020). In the human body, vitamin K represents a biomolecule important for the right function of numerous proteins, such as coagulation factors (II, VII, IX, X, protein C, and protein S), osteocalcin (bone-forming protein), or matrix-Gla protein (anti-calcification protein). Due to these health benefits, vitamin K may help prevent fractures, liver cancer, vascular calcifications, and reduce the risk of coronary heart disease (DiNicolantonio et al. 2015). Vitamin K deficiency is associated with high bleeding tendency due to low activity of coagulation factors. RDA is set at 5 to 55 μg per day for children and 55 to 65 μg per day for adults (WHO & FAO 2004). The Scientific Committee on Food concluded that there is no appropriate way to define UL for vitamin K (Turck et al. 2017).

Water-soluble vitamins

The water-soluble vitamins consist of a group of various chemical substances. Classification of these substances depends on their functions and chemical characteristics. As mentioned before, water-soluble vitamins include vitamin C (ascorbic acid) and vitamins of the B complex (Steinberg et al. 2005).

B complex is a group of vitamins that assist with the synthesis of many physiologically important biomolecules in cells and with the production of energy. They also play a significant role as coenzymes in the metabolism of amino acids, carbohydrates, glycogen, and others. They are water-soluble and the human body does not build up reserves of these vitamins. Daily replenishment is provided by the diet. The most common sources of the B complex are pure cereals, but the amounts of vitamins are often reduced by excessive polishing and refining. Although the manifestations of deficiency of B complex such as beriberi or pellagra have declined, the world is still facing sub-clinical deficiency of some B vitamins, especially pyridoxine and riboflavin (Schellack et al. 2015; WHO & FAO 2004).

Thiamine (vitamin B_1, aneurin) is a cofactor of enzymes involved in the synthesis of adenosine triphosphate (ATP) and coenzyme in the metabolism of carbohydrates and amino acids. Rich sources of thiamine are legumes, nuts (especially macadamia nuts), cereals, whole grains, yeasts, eggs, poultry, and fish. Fruits and vegetables contain low quantities of thiamine as well as polished rice, milled wheat flour, or milk. There are also many substances that may interfere with the absorption and metabolism of thiamine such as tannic and caffeic acids (polyhydroxyphenols contained in tea and coffee), or drugs (contraception, diuretics, and others) (Attaluri et al. 2018; Pacei et al. 2020). RDA is set at 1.1 to 1.2 mg per day for adults. The deficiency results in diseases called beriberi (nervous system disease) and Wernicke-Korsakoff syndrome (disease associated with alcoholism). Thiamine deficiency has been observed for example in Southeast Asian children infected with hookworm or in Thai rural elderly. Toxicity is not a problem, because the clearance is rapid and accumulation does not occur. (WHO & FAO 2004).

Riboflavin (vitamin B_2) is a water-soluble, heat-stable vitamin of the B complex. B_2 is known for its antioxidant, antiaging, anticancer, and anti-inflammatory properties and protects the body from medical conditions such as ischemia or sepsis. Riboflavin can be found in milk, livers, eggs, fish, in certain fruits and legumes, nuts, or in dark green leafy vegetables. RDA is set at 1.1 to 1.3 mg per day for adults. The deficiency of riboflavin is considered as one of the most common in developing countries where meat and milk are not consumed sufficiently. The deficiency results in glossitis (tongue inflammation), cheilosis (cracked lips), skin inflammation, or nervous system disorders. These disorders were also observed in Southeast Asian children infected with hookworm. Riboflavin is not toxic because of his limited intestinal absorption (WHO & FAO 2004; Suwannasom et al. 2020).

Niacin (vitamin B_3) includes vitamers nicotinamide and nicotinic acid. These give rise to coenzyme forms nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP), which are essential in oxidative reactions, which result in energy production. NAD and NADP are also substrates for enzymes regulating many biological functions in the human body, such as gene expression, DNA repair, or cell death (Gasperi et al. 2019). Good sources of niacin are grains (except corn), nuts, legumes, fish, and meat (Meyer-Ficca & Kirkland 2016). RDA is set at 14 to 16 mg per day for adults. The deficiency of niacin is manifested by pellagra disease. Pellagra is a chronic disease associated with dermatitis, mental changes, dementia, insomnia, apathy, brain dysfunctions, and intestinal inflammation with diarrhoea. The UL for adults is set at 35 mg per day. Long-term high oral doses of nicotinic acid lead to hepatotoxicity and dermatologic disorders (WHO & FAO 2004).

Adenine (vitamin B_4) is a derivative of purine (nucleobase) and is a part of coenzymes nicotinamide adenine dinucleotide (NAD), flavin adenine dinucleotide (FAD), and adenosine diphosphate (ADP) which play a significant role in cellular respiration. Adenine is also found in deoxyribonucleotide acid (DNA) and ribonucleotide acid (RNA) which are involved in protein synthesis. Adenosine monophosphate, a modified form of adenosine, plays a significant role in many hormonal processes as a messenger (Buang 2011). Other beneficial functions are antioxidant activity and increasing the production of antibodies by the immune system. The richest sources of adenine are brewer's yeast, whole grains, royal jelly, bee pollen, bee putty, honey, aloe vera, spirulina, kelp, and green leafy vegetables. No RDA has been established (Canadian Academy of Sports Nutrition 2020).

Pantothenic acid (vitamin B_5) is an essential vitamin for mammals and is required for coenzyme A (CoA) synthesis. CoA works as a cofactor in many enzymatic reactions, including oxidation of important biomolecules such as carbohydrates, fatty acids, amino acids, lactate, pyruvate, and ketone bodies (Tahiliani & Beinlich 1991). We can observe many symptoms of vitamin B_5 deficiency. Visible signs are personality changes, anorexia, decreased growth, depression, sleep disturbances, and infections. Deficiency of pantothenic acid also manifests in histopathological abnormalities such as ND_S, cardiac instability, muscle weakness, and abdominal pains (Smith & Song 1996). Vitamin B_5 is found in both plant and animal origin foods. The richest sources include chicken, beef, and organ meats. Plant-based foods rich in pantothenic acid are potato and tomato products and whole grains. Because of the thermally labile properties, 37 % to 47 % of the total amount of vitamin B_5 is lost during the processing and refining of whole grains.

The worst losses occur during the freezing and canning of vegetables (up to 78 %). RDA is set at 5 mg per day for adults and first deficiency signs are observed after 6 weeks, but pantothenic acid deficiencies are very rare in humans. As it is a water-soluble vitamin, toxicity does not normally occur. Mild diarrhoea may occur at high doses of 10 to 20 grams per day (Miller & Rucker 2020).

Pyridoxine (vitamin B_6) is also water-soluble vitamin. Our diet contains one of 3 forms in which vitamin B_6 occurs. It is pyridoxine, pyridoxal and pyridoxamine. These are found especially in poultry, fish, meat, nuts, cereals, and bananas. Vitamin B_6 works as a coenzyme and is involved in many reactions of lipids, carbohydrates, and amino acid metabolisms. Additionally, vitamin B_6 is involved in neurotransmitter synthesis, which is very important in neuronal signalling (Vrolijk et al. 2017). The deficiency may occur in ND_S including epileptic seizures, convulsions, and also may cause infant abnormalities, further anaemia, glossitis, and naso-lateral seborrhoea (skin disease). Vitamin B_6 deficiency is associated with a deficiency in other vitamins of B-complex, but in general, deficiency of this vitamin is rarely seen (Schellack et al. 2015; Lee et al. 2015). Nevertheless, deficiencies have been reported in Southeast Asian children infected with hookworm. RDA is set at 1.3 to 1.7 mg per day for adults and 1.9 to 2.0 mg per day for pregnant and lactating women. UL intake is set at 100 mg per day (WHO & FAO 2004). Long-term use of high doses leads to polyneuropathy (peripheral nerve disorders) and decreased vitamin B_6 function (Vrolijk et al. 2017).

Biotin (vitamin B_7) is another water-soluble vitamin of the B-complex. Biotin mainly functions in bicarbonate-dependent carboxylation reactions as a coenzyme. In humans, biotin operates with 4 carboxylases: pyruvate carboxylase, methylcrotonyl-CoA carboxylase, propionyl-CoA carboxylase, and acetyl-CoA carboxylase. Biotin works as a carrier and transfers bicarbonate to the substrate, where the carboxyl product is formed (WHO & FAO 2004). Biotin is widely found in liver, egg yolks, whole grains, and in some vegetables. Signs of deficiency are manifested by dermatitis, alopecia, conjunctivitis, or abnormalities of the central nervous system such as delayed development in infants, lethargy, hypotonia, hallucinations, and paraesthesia of the extremities. People who consume a large amount of raw egg white may have problems with deficiency due to decreased bioavailability of biotin caused by the biotin-binding protein avidin (Zempleni & Kuroishi 2012). RDA is set at 30 μg per day for adults and

35 μg per day for breastfeeding women. Biotin has limited intestinal absorption, so toxicity does not occur (WHO & FAO 2004).

Inositol (vitamin B_8) is a derivate of cyclohexane, also known as sugar alcohol. Inositol exists in 9 isomers, among which the myo-inositol is the most abundant. Inositol functions as a second messenger in cells and is also involved in genetic information transmission. In the human body, inositol is synthesized especially in kidneys, in amounts of few grams per day. Food sources include high bran content cereals, cocoa, and some plants of the Cucurbitaceae, Fabaceae, and Poaceae family. No deficiency of inositol has been identified in humans (Food Browser 2020).

Folic acid (vitamin B_9, folate) is a water-soluble vitamin involved in red blood cell formation, protein metabolism, and purines and pyrimidines synthesis. Folic acid also lowers the risk of neural tube birth defects and coronary heart disease. Good sources of folic acid are organ meats, mushrooms, yeasts, and especially abundant sources are green leaves of many species, oranges, and whole grains. Here also comes the name of folic acid, where *folium* means leaf in Latin. Deficiency of folic acid is associated with neural tube birth defects and megaloblastic anaemia, which is indiscernible from that caused by vitamin B_{12} deficiency. RDA is set at 400 μg per day (Mitchell et al. 1941; Steinberg et al. 2005; Schellack et al. 2015). UL for folic acid is 400 μg per day for adults (Yang et al. 2010). Folic acid is not toxic for human, but in patients undiagnosed with pernicious anaemia may cause neurological injury and in drug-treated epileptic patients the seizure control may be affected (Butterworth & Tamura 1989).

Para-aminobenzoic acid (vitamin B_{10}, PABA) is a slightly basic chemical substance found in all living species from humans to bacteria. The source with the highest concentration is pineapple. Other sources of PABA include grains, eggs, meat, and milk. PABA is used as a sunscreen, and also to treat skin diseases (vitiligo, morphoea, dermatomyositis, and others), anaemia, infertility in women, rheumatic fever, systematic lupus erythematosus (autoimmune disease), headache, and constipation. When taken in high doses, PABA can cause several kidney, blood, and liver problems (Food Browser 2020; WebMD 2021).

Choline (vitamin B_{11}) is a weakly basic compound of lecithin that is found in organs of many species. In the human body, choline functions as a precursor of acetylcholine and is involved in lipid metabolism. Humans can synthesize small amounts of choline, but for maintaining health, supplementation through diet is necessary. Required intake is between 425 and 550 mg per day. Rich sources include peanuts, liver, milk, and eggs. Choline deficiency leads to liver diseases (Food Browser 2020).

Cyanocobalamin (vitamin B_{12}) is a water-soluble vitamin that is important in methyl transfer, nucleic acid metabolism, and synthesis and reparation of myelin (Schellack et al. 2015). Vitamin B_{12} is necessary for the myelination and normal function of the central nervous system. The richest sources of vitamin B_{12} are liver and red meat of ruminants, followed by veal and lamb meat. Other sources than animal-origin are inadequate (Rizzo & Laganà 2020). The deficiency of cyanocobalamin leads to NDs (degeneration, peripheral neuropathy, tingling, numbness), megaloblastic anaemia, and fatigue (Stabler 2013; Schellack et al. 2015). Infants of vegan mothers, strict vegans, vegetarians, and the elderly are groups in which cyanocobalamin deficiency is common (Stabler 2013). RDA is set at 2.4 μg per day for adults and 2.6 to 2.8 μg for pregnant and lactating women. No toxic effects of cyanocobalamin were observed and therefore there is no UL of supplementation (Allen 2012).

Vitamin C is an essential water-soluble vitamin, that cannot be naturally synthesized in the human body and must be ingested through diet. Due to the protective role of vitamin C, its supplementation became a must because of the higher pollution levels of the environment. Although most of the animal species have the ability to synthesize ascorbic acid in their bodies, humans suffer from a mutation in the DNA, which codes the enzyme gulonolactone oxidase, the main enzyme responsible for vitamin C synthesis (Yussif 2019). In the human body, vitamin C takes part in many physiological processes such as collagen synthesis, iron absorption, or immune stimulation, and works also as an enzyme cofactor and antioxidant. Ascorbic acid is an excellent free radical scavenger, having a very effective capability to donate reducing equivalents and having stable newly formed monodehydroascorbate radical (Paciolla et al. 2019). There are many abundantly available sources of vitamin C in nature. The richest sources are citrus fruits, strawberries, kiwi, cantaloupe, papaya, broccoli, and lesser-known species Indian gooseberries (*Phyllanthus emblica*) (Devaki & Raveendran 2017). Hypovitaminosis C (deficiency of vitamin C) is frequent especially in old people, homeless persons, or people who live alone. The deficiency is caused by the lack of consumption of fresh fruits and vegetables and manifests approximately after 3 months by scurvy. Other signs of hypovitaminosis C are weakness, vascular purpura, myalgia (muscle pain), arthralgia (joint ache), loss of teeth, anaemia, hypocholesterolemia, and hypoalbuminemia. RDA is set at 110 mg per day for adults (Fain 2004). Although ascorbic acid is a water-soluble vitamin and our body is able to excrete an excessive amount of this vitamin in urine, the long-term high dose of vitamin C can cause cellular toxicity and DNA damage (Kim et al. 2018).

4.2. Thailand

Until 1949, Thailand (meaning Land of the Free) was known as Siam. Today, the official name is the Kingdom of Thailand. The form of government is parliamentary (bi-cameral) democracy with a constitutional monarchy. The capital city is Bangkok, also known as Krung Thep, which means the City of Angel in Thai. Administratively, Thailand is divided into the Bangkok Metropolitan area, 4 regions, and 76 provinces (changwats). The country covers an area of 513,120 km^2. Located in the mainland of Southeast Asia, Thailand is a country of hills, mountains, plains, and a long coastline along the Andaman Sea (740 km) and the Gulf of Thailand (1,875 km). Thailand has about 400 islands, most of them located in the Andaman Sea. Another important body of water is the Mekong River, which forms Thailand's natural boundary with Laos. Continental coordinates of Thailand are defined by latitude 20° 28' N and 5° 36' S and longitude 105° 38' E and 97° 22' W. Thailand borders Lao People's Democratic Republic to the north and east, Myanmar to the north and west, Cambodia to the east, and Malaysia to the south. Thailand is a multi-ethnic country, and the population is about 64.1 million people. The official and national language is the Thai language, which is a tonal language with different dialects. The script of the Thai language was created by King Ramkhamhaeng the Great of the Sukhothai Kingdom in 1283. Other languages spoken are Malay, Chinese, and English, which is a compulsory subject of the curricula of secondary schools. English is widely spoken and understood throughout the country. The currency unit is baht. Every baht is divided into 100 satangs. The banknotes are denominations of 20 baht (green), 50 baht (Blue), 100 baht (red), 500 baht (purple), and 1,000 baht (brown). Exchange rates against US dollars averaged 31.0 baht per 1 US dollar (Royal Thai Embassy 2021). The national flag consists of 5 horizontal bands of red, white, and blue. Colours represent the unity of the nation, purity of religion, and the monarchy. The vast majority of the population (more than 90 %) are Buddhists. Other major religions practiced are Christianity, Hinduism, Islam, and Sikhism. The Thai Constitution does not mention any sects or religions as a national religion and grants complete freedom of worship for all citizens. Chang Thai (Thai elephant) and Sala Thai (Thai Pavilion) are considered national symbols. Sala Thai is an architectural symbol of the country, which reflects the skills of Thai artisans. As far as the economy is concerned, the main exports comprise manufacturing products (74 %), agricultural products (13 %), agro-industrial products (8 %), and mining and others (5 %). The main manufacturing products include automobiles, automotive parts, computers and components, jewellery, rubber products, plastic pellets, and chemical industry products. In the terms of agriculture, the main export items are natural rubber, rice, tapioca products, processed chicken, frozen seafood, and of course fruits and vegetables (FAO 2011; Royal Thai Embassy 2021).

4.2.1. Climate

According to Köppen climate classification, Thailand has a predominantly tropical wet and dry climate in the north and a tropical monsoon climate in the south (Khedari et al. 2002). Tropical rainforests are found in several sections in the western and southern areas of the country. In the far north, there are also areas of a temperate climate with warm summers and dry winters. Monsoon rains together with the location of Thailand near large water bodies chiefly influence the climate. There are 2 seasonal monsoons in Thailand. The southwest monsoon operates from May to October and brings heavy rainfall. In the period from November to February, the northeast monsoon brings colder and drier weather. In Thailand, 3 seasons alternate throughout the year. The rainy season lasts from mid-May to mid-October, where August and September are the rainiest months with a rainfall range of 250–400 mm per month. The winter season lasts from mid-October to mid-February. The coldest months are December and January with average temperatures around 20–25 °C. The summer season lasts from mid-February to mid-May. April is usually the warmest month with average temperatures around 32–36 °C. In Bangkok and surrounding areas, the average daily temperatures are high (31–32 °C), even in the winter. On the contrary, the northwest mountainous areas near Laos and Myanmar have comfortable temperatures throughout the year. The highest measured temperature in the territory of Thailand is 44.5 °C, set on April 1960, in Uttaradit. The lowest measured temperature is –1.4 °C, set in January 1974, in Sakon Nakhon. During the rainy season, there is a danger of weather hazards. Thunderstorms, floods, and tropical cyclones often occur. May is the month with the highest frequency of thunderstorms. Tropical cyclones come to Thailand's shores from the South China Sea or the Pacific Ocean. The southern part of the country is an area with a high incidence of typhoons with wind speeds above 120 km per hour. In 1997, the typhoon Linda hit the Prachuap Khiri Khan province with devastating effects. Also, heavy rainfall causes season floods every year (Weather Atlas 2021).

4.2.2. Biodiversity

Thailand is a part of the Indo-Burma Biodiversity Hotspot. Biodiversity hotspots are 35 biogeographical regions (36 in some literature) that have both extreme threats to their vegetation integrity and exceptional endemism. They are global conservation priorities (Sloan et al. 2014). Indo-Burma Biodiversity Hotspot is located on the Indochinese Peninsula and comprises Cambodia, Laos, Myanmar, Thailand, Vietnam, and a few parts of southern China and northeast India. The topography is characterized by series of mountain ranges that descent from the Himalayan chain ads its southeast extensions. Major rivers include Ayeyarwady, Salween, Chao Phraya, Mekong, and Red, whose floodplains and deltas are the main centres of human settlement. The biota of Indo-Burma is a mixture of floras and faunas of southern China, the Himalayas, India, and the Sundiac Region, with a significant endemic component, particularly in the case of plant species. Endemic centres include montane isolates, limestone karst areas, and lowland evergreen areas. A conservative estimate of total plant diversity reveals about 13,500 species of vascular plants, of which 7,000 (52 %) are endemic. Similarly, 74 of the 1,277 bird species and 71 of the 430 mammal species are endemic. Indo-Burma has the largest human population of the world's 35 hotspots, which is reflected in the fact that the remaining natural habitat accounts for only 5 % of the original area. Major current threats to the hotspot's biodiversity are the expansion of agriculture, infrastructure development, timber extraction, and rapacious illegal trade in wildlife (Tordoff et al. 2012). Figure 1 shows the location of the Indo-Burma Biodiversity Hotspot and the top 5 high-priority areas. These include Mae Klong Basin in Thailand (1), Ayeyarwady River in Myanmar

(2), Inner Gulf of Thailand (3), Mae Fang in Thailand (4), and Nong Bong Kai in Thailand (5) (Tantipisanuh et al. 2016).

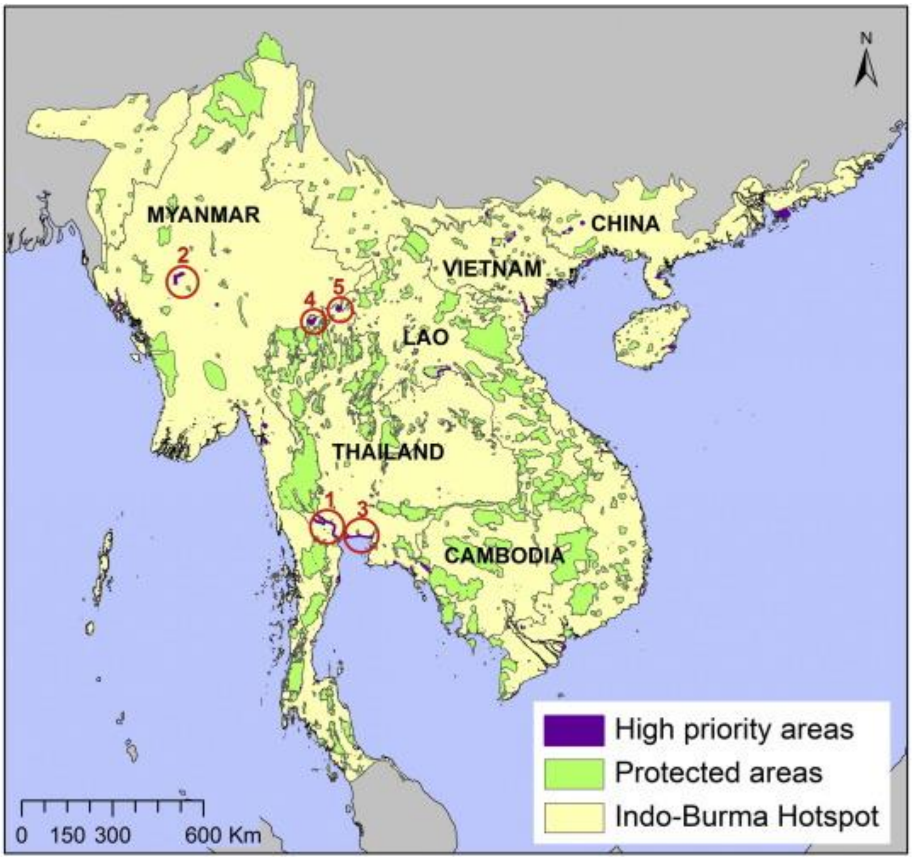

Figure 1. Indo-Burma Biodiversity Hotspot: (Tantipisanuh et al. 2016)

Thailand is one of the most biodiverse areas in the world. There are 15 mountain ranges, countless watersheds, and river basins connected to the Mekong, which together with the Gulf of Thailand and the Andaman Sea form a juncture distribution for various plant species. These include temperate plant species, sub-alpine flora species from the Himalayas and China, tropical plant species from Indochina, and tropical species originating in other parts of Asia. More than 15,000 plant species which represent 8 % of the world are found in Thailand. Thailand's unique biodiversity is supported by a large variety of habitats, landscapes, and ecosystems, which are threatened mostly by human activity. In 1961 a lush forest cover was 53.35 %. Nowadays, forest areas cover about 33 % of the country's total area with at least 18 % of conserved forests. Several wild plant species have been irretrievably lost. Furthermore, between 2003–2005 hundreds of thousands of wild orchids were poached and sold to collectors and orchid farms. Threatened species include 121 mammals, 184 birds, 33 reptiles, 5 amphibians, 218 fish, and more than 1,130 plants (Convention on Biological Diversity 2021). Many species are endemic to Thailand, for example, the herb *Derris reticulata* Craib (Sirichamorn 2014).

4.2.3. Agriculture

Thailand is predominantly an agricultural country. The total area of agricultural land in 1961 was 11,653,000 ha (the total country area is 51,312,000 ha). In 2017 the total area of agricultural land reached 22,110,000 ha which is the most in the entire history. Employment in agriculture was much higher in 1961 (82.40 % of labour force) than in 2017 (30.92 % of labour force). In Thailand, employment in agriculture is still declining and, conversely, a growing trend can be observed in the sectors of services and industry, where employment is 45.47 % and 23.61 % respectively. Agriculture and forestry together with fishing account for 8.33 % of gross domestic product. It is another declining trend, because, in 1961 agriculture, forestry, and fishing accounted for 36.44 % of gross domestic product. These facts suggest that the country has undergone significant agricultural and economic development. Main crops cultivated in Thailand are especially paddy rice, rubber, cassava, maize, mango, coconut, and soybeans. In 2017, these 7 crops occupied 16,683,243 ha out of a total of 16,810,000 ha of arable land. Other crops cultivated are mainly fruits and vegetables such as bananas, cashew nuts, garlic, grapefruits, papayas, pineapples, tangerines, taro, tomatoes, and watermelons. If we focus on livestock, the most numerous species in Thailand (2017) are pigs (7,882,009 heads), followed by cattle (4,680,000 heads), buffaloes (1,253,518 heads), goats (467,502 heads), chickens (277,081 heads), and sheep (40,984) (FAOSTAT 2020). Overall, Thai farming is considered small-scaled since most of the farms are owned and operated by family members. These farms and with them the necessary skills are inherited from one generation to the next. The average size of a farm is only 4 ha per household (FAO 2021).

In Thailand, homegardens (Figure 2) are a very important source of various crops. Homegardens function as multi-use, multi-story, small-scale land-use systems for satisfying the immediate needs of households. They provide various food crops, medicinal plants, and many other human needs such as ornamental plants. Homegardens are also important sites of domestication of wild medicinal and food plant species and reflect the culture of ethnic groups by involving the management of many useful plant species over prolonged periods of time (Srithi et al. 2012).

Figure 2. Thai homegarden: (Wiens 2021)

4.2.4. Thai cuisine

Influenced by Indian and Chinese cooking art, Thai cuisine has blended those together and created the originality of its own. Thai food is considered scrupulously cooked and delicate in dish decoration. Carved fruits and vegetables are often used to embellish the serving, making it a graceful culinary art, not only for its taste but also its appearance. In Thailand, rice is the main staple food. Steamed or boiled rice (sticky rice in the Northeast region) is the elemental part of the meal and is combined with vegetables, fish, and other meat cooked with various spices such as garlic, chilli, lemongrass, tamarind, coriander, basil, and peanuts. The taste of Thai food is usually spicy and hot. Thai cuisine has also a wide variety of sweet desserts and snacks. Most of the desserts are made of coconut milk, sugar, and eggs. Desserts such as Kanom Buang (dough filled with scraped coconut, egg yolk, and green onion) or Sang Kaya (custard made from coconut milk, eggs, and sugar, usually eaten with sticky rice steamed with coconut milk) are worth tasting. When it comes to fruits, a parade of different kinds of tropical fruits can be seen all year round. To name just a few, there are banana, durian, mangosteen, papaya, and rambutan. But Thailand is not only a kingdom of fruits but also the kingdom of seafood.

As Thailand has a long coastline, fresh supplies of fish, crabs, prawns, lobsters, and other shellfish to cities such as Bangkok or Phuket are always available (Asia Discovery 2011).

As a result of its unique characteristics and rich flavours derived from a large variety of ingredients, Thai cuisine has become globally popular. In Thailand, each dish has its own unique flavour from different signature ingredients. The preparation and cooking processes are delicate and detailed. Working with traditional Thai ingredients is a feast for the senses, with a vast array of flavours, be they sweetness, saltiness, or sourness, not to mention fiery chilli peppers and the richness of coconut milk. Such ingredients add to flavour and colour of Thai recipes, as well as the popularity of this cuisine among Thais and foreigners alike. The variety of ingredients such as herbs and spices has also led to Thai food being widely consumed in foreign countries as a healthy diet. In addition, Thai cuisine has 4 regional variations. These are corresponding to the 4 geographical regions of the country. Each of them has its own unique characteristics derived from local history, resources, and tastes. In the South region, Thai cuisine has a strong spicy flavour with turmeric as a signature ingredient in almost every dish. This spice is also used for the healing of stomach ulcers. Mountainous topography and the cooler climate of the North region call for dishes fattening to warm the body. The Northeast or Isaan region is known for its 2 main flavours: spiciness and saltiness. In this region, sticky rice is the main accompaniment to meals. Last, but not least is the Central region, which is the most gastronomically blessed region of Thailand. There is wide access to ingredients from all over the country. Countless varieties of snacks, chilli sauces, dips, curries with or without coconut milk, spicy salads, and Thai desserts make this region a true gastronomic centre of the whole country. Popular dishes include Tom Yum Gung (spicy sour prawn soup), Pad Thai (Thai-style stir-fried flat rice noodles, Figure 3), Som Tam (papaya salad), Gaeng Khiao Wan (green curry), Khao Pad (Thai-style fried rice), and Nam Tok Moo (Thai-style spicy pork salad) (Thailand Foundation & Ministry of Foreign Affairs of Thailand 2014).

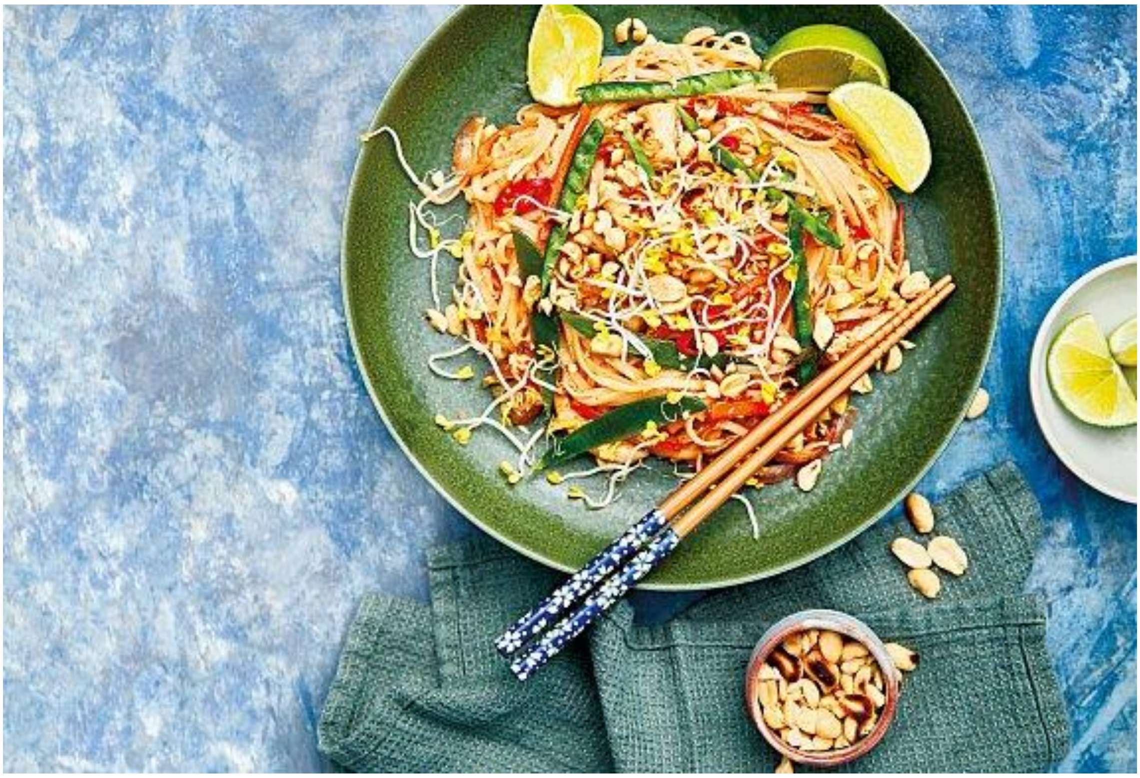

Figure 3. Pad Thai: (F.O.O.D. 2019)

4.2.5. Health

Thailand is a country that has had experience with alleviating undernutrition since the 1980s, particularly in mothers and children. In the past, Thailand also faced major nutrition problems such as protein-energy malnutrition, iron deficiency anaemia, and other micronutrient deficiencies. During the last years, Thailand has become a middle-income developing country with an aging population and developing urban sector. Agriculture has been geared for both local and international markets. Also, agriculture has changed from traditional to modern large-scale food production (Tontisirin et al. 2013).

Nowadays, supermarkets and chain stores are replacing traditional markets. Simultaneously, new challenges in nutrition are emerging. As in developed countries, problems related to lifestyle changes, reduction of physical activity, and consumption of processed food also occur in Thailand. The rapid growth of agroindustry and innovations of food systems allow access to a greater variety of foods, including those containing high levels of sugar, fat, and salt. At the same time, the consumption of fruits and vegetables is low. In 2011, Thai males consumed 268 g and females 283 g of fruits and vegetables per day, even though Thailand produces a great quantity and variety of such crops. Although Thailand is a food surplus country, food accessibility at the household level remains a problem in the rural remote areas. An increase in food prices and production costs have a great impact on Thailand's rural poor. Such households face the risk of food insecurity as they may reduce the intake of more nutritious food. Consequently, in Thailand, the current challenge in nutrition is double-burden malnutrition, wherein increasing trends in non-communicable diseases, overweight and obesity coexist alongside remnants of undernutrition (Isvilanonda & Bunyasiri 2009; Tontisirin et al. 2013). Non-communicable diseases are the No. 1 health issue in Thailand. In the past decade, non-communicable diseases have been the cause of more than 75 % of all mortalities in Thailand of which around 55 % was the death of people under 70 years, which is considered as premature death by WHO. Major diseases causing premature death in Thailand are cerebrovascular disease, Ischemic heart disease, diabetes, and chronic obstructive pulmonary disease. Following this, the Ministry of Public Health developed 5-Year National Non-communicable Diseases Prevention and Control Strategic and Action Plan (2017–2021) in alignment with the 20-year national strategy on Thailand in the sector of human potential development (Ministry of Public Health 2017).

4.3. Underutilized crops

Underutilized or neglected crops are species that hold significant potential for improving diets and nutrition while protecting biodiversity in agricultural landscapes and food systems. These can be domesticated, semi-domesticated, or wild species such as fruits, vegetables, nuts, roots, tubers, pulses, grains, food trees, and others (Hunter et al. 2019). According to Padulosi et al. (2013), underutilized and neglected species are "useful plant species which are marginalized, if not entirely ignored by researchers, breeders and policy makers". They are usually non-timber forest species, which are highly adapted to specific local environments. Also, underutilized crops are not traded as commodities (Padulosi et al. 2013).

Thailand has ideal conditions for growing tropical and subtropical crops throughout the year. Thousands of wild species are found growing locally in various systems. These systems include cultivated grown in home gardens and commercial plantations, unattended growth in the villages, and growth in the forests. Many varieties of this species are grown only for local uses. Unfortunately, only a limited source of information on such species exists. One of them is the PROSEA publication – "Plant Resources of South-East Asia", which provides information on some of the underutilized crops. If we focus on fruit species, which in some cases can also provide vegetables, for example in the form of leaves of shoots, we can divide underutilized species into 3 main groups (Subhadrabandhu 2001):

1. Species with potential for commercial development (species currently cultivated in small-scale mixed orchards and grown together with other economic crops).

2. Species with possible development potential for home garden use (species that are valuable genetic resources, but it may be difficult to bring them into Thailand's markets).

3. Species without current development for economic uses (species grown in forests, along roadsides, or unattended in wasteland, valuable for local villagers, but also as genetic resources for further scientific investigation).

Over the last few decades, the human diet has changed a lot. The composition of the diet is very similar around the world, dominated by wheat, rice, and maize at the expense of alternative staples such as yam, sweet potato, cassava, rye, millets, and sorghum. In addition, the consumption of fruits and vegetables is insufficient worldwide. Although the underutilized and neglected species are under-researched, they frequently have superior nutrition content compared to the crops currently dominating our food systems. Therefore, these species can be a tool to combat malnutrition, but also other worldwide health issues such as diseases of affluence and environmental issues such as a decline in biodiversity (Hunter et al. 2019).

Today there are species that were previously considered underutilized, but due to their excellent properties have become known to the scientific community and later to the whole of society. Such species include, for example, palm *Euterpe oleracea* Mart. (acai berry) and low-growing shrub *Myrciaria dubia* (Kunth) McVaugh (camu-camu). Acai is a small, round drupe that is green when unripe and ripens to a dark purple colour. It is native to Central and South America and grows widely in the Amazon as well as swamps and flood plains. The fruit is consumed raw, or as a juice, which is commercially used in jelly, syrup, ice cream, liquors, energy drinks, and others. Acai berry is known as a rich source of vitamins A, B_1, C, E, calcium, iron, phosphorus, and antioxidants such as anthocyanins and polyphenols (Marcason 2009; Neto et al. 2010). Camu-camu is another fruit species originating in South America. Its fruits are considered the richest natural source of vitamin C in Brazil. They are also an important source of antioxidants (polyphenols, carotenoids), calcium, iron, phosphorus, potassium, and various amino acids. Products such as extract, juice, pulp sherbet, and puree are exported to world markets, especially to Europe and Japan (Akter et al. 2011).

The species mentioned above are both native to South America, where biodiversity hotspots such as the Atlantic Forest of Brazil, Cerrado, and Tropical Andes are found. As mentioned before, Thailand is a part of the Indo-Burma Biodiversity Hotspot (Sloan et al. 2014). Even there, countless nutritionally interesting species can be found. Some of them were considered underutilized, but nowadays they are already being traded at least in Asia and are becoming known to the public. Examples of such species are *Syzygium cumini* (L.) Skeels (jambolana) and *Morinda citrifolia* L. (noni, Figure 4). Jambolana is a multipurpose plant with small black-purple drupes, which are consumed fresh or processed into popular wine. This species is indigenous to the Indian subcontinent, where it is known also as a "jambul" or "kala jamun". Because of its rich nutritional and medicinal value, jambolana has been used in the treatment of various diseases. Seeds, leaves, and bark have beneficial features such as anti-inflammatory, antioxidant, antibacterial, and anticancer. Ripe fruits were found to have cardiovascular effects. Furthermore, jambolana has antiallergic, antifungal, anticlastogenic, antidiarrheal, antifertility, antihyperlipidemic, antihypertensive, radioprotective, chemoprotective, and hepatoprotective effects (Agarwal et al. 2019). Noni is another nutritionally interesting plant with medicinal properties. In Asia, we can also come across the names "Indian mulberry", "painkiller bush" or "nhau". It is also called starvation fruit. Despite its bitter taste and strong smell, noni is nevertheless eaten as a famine fruit and in some of the Pacific islands, noni is even considered a staple food. In Polynesian medicine, it has been used for more than 2,000 years. Ripe fruits of this evergreen shrub have a strong butyric acid smell and flavour. Recent studies have shown the antioxidant and antibiotic properties of the fruits. In addition to fruits, leaves are also eaten by Polynesians and other communities, and roots are used as a dye. Noni is known on the international market especially in the form of juice (Chan-Blanco et al. 2006; Pandiselvi et al. 2017).

Figure 4. ***Morinda citrifolia*****:** (Our Tropical Soil 2019)

During the Green Revolution, the focus of agricultural research was on increasing quantity, not quality. As a result, diets deficient in essential micronutrients and vitamins persist in less developed parts of the world. Underutilized species have the potential to contribute to food security at local and regional levels. Due to their significant nutritional values, they are a tool to combat undernourishment and lack of minerals in human nutrition. Species that are rich in antioxidants can even help to fight against diseases of affluence such as CVDs and cancer. At the national level, underutilized species can strengthen the food and buffer economy of the country as well as the social shock that might occur because of concentrating on fewer and fewer crops. Underutilized species have lower yields but are more resistant to biotic stresses than well-known high-yield crops. They provide dependable harvests on poor soils or in unfavourable climatic conditions (Padulosi et al. 2013).

Table 1 shows underutilized fruits and vegetable species originating in Thailand, South or Southeast Asia, and their content of antioxidants, minerals, and vitamins. These species are traditionally grown, sold in markets, and consumed by the locals in Thailand, but they remain almost not known for the rest of the world.

Table 1: Thai underutilized fruit and vegetable species and their nutritional value

No	Scientific name[1]	Family[1]	Origin[2,3]	Edible part[2,3]	Contained substances[3]	References
1	*Aegle marmelos* (L.) Corrêa	Rutaceae	SE Asia, Thailand	pulp, pericarp, leaves, shoots	**antioxidants:** EC_{50} 6.21 µg dw/g DPPH; 102.74 µmol TE/g dw (FRAP assay); phenolics 87.34 mg GAE/g dw; flavonoids 15.20 mg CE/g dw; carotenoids 32.98 µg/g dw **vitamins:** vitamin C 26.17 mg/100 g dw	Charoensiddhi & Anprung 2008
					antioxidants: α-tocopherol 27 mg/100 g dw; β-carotene 8600 µg/100 g dw; glutathione 580 mmol/100 g dw; flavonoids 2.4 mg/100 g of extract; polyphenols 2.4 g/100 g of extract **vitamins:** vitamin C 260 mg/100 g dw	Reddy & Urooj 2013
					antioxidants: carotene 55.0 mg/100 g **minerals**: 1.70 g/100 g **vitamins:** thiamine 0.13 mg/100 g pulp; riboflavin 1.19 mg/100 g pulp; niacin 1.1 mg/100 g pulp; vitamin A 186 IU/100 g pulp; vitamin C 8–18 mg/100 g pulp	Pandey et al. 2015
					minerals: Cu 0.19 mg/100 g; Zn 0.28 mg/100 g; Ca 78.0 mg/100 g; K 603 mg/100 g; P 51.6 mg/100 g; Mg 4.0 mg/100 g; Fe 0.55 mg/100 g **vitamins:** vitamin A 55 mg/100 g; thiamine 0.13 mg/100 g; riboflavin 1,200 mg/100 g; vitamin C 8 mg/100 g	Venthodika et al. 2020
2	*Alpinia malaccensis* (Burm.f.) Roscoe	Zingiberaceae	SE Asia	rhizome	**antioxidants:** phenolics 564 mg GAE/100 g; AEAC 745 mg ascorbic acid/100 g	Chan et al. 2008

3	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	SE Asia, Thailand	corms (cooked), leaves, petioles	**antioxidants:** flavonoids 36.88 mg RE/g (70 % hydroalcoholic extract); flavonoids 46.33 mg RE/g (methanolic extract); phenolics 6.25 mg catechol equivalent/g (70 % hydroalcoholic extract); 12.67 mg catechol equivalent/g (methanolic extract)	Nataraj et al. 2009
					minerals: Ca 5,000 mg/100 g; P 3,400 mg/100 g; vitamin A 26,000 IU/100 g	Singh & Wadhwa 2012
					antioxidants: corms: phenolics 7.01 mg GAE/g (cooked 10 min), 5.98 mg GAE/g (20 min), 4.74 mg GAE/g (30 min), 4.37 mg GAE/g (40 min); DPPH activity 6.46 μmol TE/g (10 min), 5.43 μmol TE/g (20 min), 4.35 μmol TE/g (30 min), 2.74 μmol TE/g (40 min)	Kumar et at. 2017[b]
4	*Ampelocissus martini* Planch.	Vitaceae	SE Asia, Thailand	grapes	**antioxidants:** IC_{50} 0.974 DPPH (green colour grapes), IC_{50} 39.620 DPPH (red colour grapes), IC_{50} 1.380 DPPH (black colour grapes); 304.740 mmol $FeSO_4$/100 g FRAP (green colour grapes), 365.0 mmol $FeSO_4$/100 g FRAP (red colour grapes), 612.120 mmol $FeSO_4$/100 g FRAP (black colour grapes)	Jenjira et al. 2013
					antioxidants: crude extract: phenolics 0.02 mg GAE/g (hexane solvent), phenolics 1.28 mg GAE/g (ethyl acetate solvent), phenolics 3.68 mg GAE/g (methanol solvent); flavonoids 2.84 mg RE/g (hexane solvent), flavonoids 3.93 mg RE/g (ethyl acetate solvent), flavonoids 5.76 mg RE/g (methanol solvent)	Vittaya 2019

5	*Antidesma bunius* (L.) Spreng.	Phyllanthaceae	E Asia, Thailand	pulps, leaves	**antioxidants:** antioxidant activity IC_{50} 1717 mg/mL **vitamins:** vitamin C 7.8 mg/100 g	Khomdram & Shantibala Devi 2010
					antioxidants: IC_{50} 395.002 mg/mL DPPH; IC_{50} 105.331 mg/mL ABTS; IC_{50} 24.366 mg/mL H_2O_2; FRAP 61.583 mmol TE/g (dry extract) **minerals:** freeze dried fruits: Na 5.377 mg/100 g; K 3,043.852 mg/100 g; Ca 787.9 mg/100 g; Mg 250.703 mg/100 g; Fe 7.579 mg/100 g, Zn 2.903 mg/100 g; Cu 1.774 mg/100 g; Mn 7.616 mg/100 g; Co 0.390 mg/100 g	Islary et al. 2017
					antioxidants: phenolics 11.57 mg GAE/g of fruit extract; flavonoids 0.30 mg QE/g of fruit extract; anthocyanins 3.76 mg C3G/g of fruit extract; IC50 14.47 μg/mL DPPH	Krongyut & Sutthanut 2019
6	*Antidesma velutinosum* Blume	Phyllanthaceae	E, SE Asia, Thailand	pulps	**antioxidants:** carotenoids 335 μg/100 g; phytosterols 22.13 mg/100 g; phenolics 973 mg GAE/100 g; 61 μmol TE/g DPPH; 118 μmol TE/g FRAP; 115 μmol TE/g ORAC **minerals:** Ca 325 mg/100 g; P 46 mg/100 g; Na 11 mg/100 g; K 230 mg/100 g; Mg 115 mg/100 g; Fe 0.58 mg/100 g; Cu 0.11 mg/100 g; Zn 0.43 mg/100 g **vitamins:** vitamin C 2 mg/100 g; vitamin E 0.96 mg/100 g	Judprasong et al. 2013

7	*Archidendron jiringa* (Jack) I.C.Nielsen	Leguminosae	E Asia, Thailand	seeds, leaves, flowers, pulps	**minerals:** seeds: Ca 23 mg/100 g; P 38 mg/100 g; Fe 0.7 mg/100 g **vitamins:** vitamin A 658 IU/100 g; thiamine 0.14 mg/100 g; riboflavin 0.01 mg/100 g; niacin 0.4 mg/100 g; vitamin C 8.0 mg/100 g	FAO 2001
					antioxidants: anthocyanin 104.44 mg/100 g (variety Gajah); anthocyanin 166.72 mg/100 g (variety Padi) **vitamins:** peel of variety Gajah: vitamin C <0.07 mg/100 g; vitamin E 0.92 mg/100 g; peel of variety Padi: vitamin C <0.07 mg/100 g; vitamin E 0.91 mg/100 g	Hidayah et al. 2020
8	*Artocarpus integer* (Thunb.) Merr.	Moraceae	SE Asia, Thailand	pulps, seeds, leaves	**minerals:** dw: flesh: K 434 mg/100 g (ripe), 288 mg/100 g (unripe); Mg 46 mg/100 g (ripe), 41 mg/100 g (unripe); Mn 4.3 mg/100 g (ripe), 5.2 mg/100 g (unripe); Ca 3.4 mg/100 g (ripe), 5.1 mg/100 g (unripe); Zn 2.0 mg/100 g (ripe), 1.9 mg/100 g (unripe); Na 1.1 mg/100 g (ripe), 0.8 mg/100 g (unripe); Cu 1.1 mg/100 g (ripe), 1.0 mg/100 g (unripe); Fe 0.5 mg/100 g (both ripe and unripe); Co 0.4 mg/100 g (ripe), 0.3 mg/100 g (unripe); Ni 0.2 mg/100 g (both ripe and unripe); Cd 0.1 mg/100 g (both ripe and unripe)	Lim et al. 2011

					seed: K 609 mg/100 g (ripe), 250 mg/100 g (unripe); Mg 65 mg/100 g (ripe), 32 mg/100 g (unripe); Mn 5.5 mg/100 g (ripe), 5.1 mg/100 g (unripe); Ca 2.9 mg/100 g (ripe), 2.3 mg/100 g (unripe); Zn 1.9 mg/100 g (ripe), 0.9 mg/100 g (unripe); Na 1.2 mg/100 g (ripe), 0.8 mg/100 g (unripe); Cu 1.0 mg/100 g (ripe), 0.7 mg/100 g (unripe); Fe 0.7 mg/100 g (ripe), 0.6 mg/100 g (unripe); Co 0.3 mg/100 g (ripe), 0.2 mg/100 g (unripe); Ni 0.2 mg/100 g (both ripe and unripe); Cd 0.1 mg/100 g (both ripe and unripe)	
					antioxidants: phenolics: 21.29 mg/g (peel), 11.87 mg/g (seed), 4.40 mg/g (flesh); flavonoids: 17.45 mg/g (peel), 3.58 mg/g (seed), 0.82 mg/g (flesh); carotenoids: 1.17 mg/g (peel), 1.09 mg/g (flesh), 0.72 mg/g (seed); 218.91 µmol/g FRAP (peel), 76.58 µmol/g FRAP (seed), 13.59 µmol/g FRAP (flesh); 11.93 mg/g ABTS (peel), 7.71 mg/g ABTS (seed), 3.97 mg/g ABTS (flesh)	Abu Bakar et al. 2015
					antioxidants: phenolics 21.45 mg GAE/100 g fw; flavonoids 158.31 mg QE/100 g fw; DPPH scavenging activity 15.42 % inhibition at 1 mg/Ml	Anantachoke et al. 2016
9	*Baccaurea dulcis* (Jack) Müll.Arg	Phyllanthaceae	SE Asia, Thailand	pulp	no data	-
10	*Baccaurea motleyana* (Müll.Arg.) Müll.Arg.	Phyllanthaceae	SE Asia, Indonesia, Thailand	pulp	**minerals: Ca** 2 mg/100 g; P 20 mg/100 g **vitamins:** vitamin C 55 mg/100 g; thiamine 0.03 mg/100 g; riboflavin 0.09 mg/100 g	Peiris 2007

					antioxidants: phenolics 21 mg/g	Ismail et al. 2012
11	*Baccaurea racemosa* (Reinw. ex Blume) Müll.Arg.	Phyllanthaceae	SE Asia	pulp	**minerals:** Ca 53.97 mg/100 g **vitamins:** vitamin C 2.94 mg/100 g	Rohyani et al. 2015
					antioxidants: pericarp: IC_{50} 1396.88 μg/mL (ethanol extract); mesocarp: IC_{50} 6943 mg/mL (ethanol extract); vitamin C IC_{50} 36.889 mg/mL	Juwita et al. 2020
12	*Baccaurea ramiflora* Lour.	Phyllanthaceae	E Asia, Thailand	pulp, leaves, flowers	**minerals:** fruit: Ca 0.158 %; Mg 0.504 %; N 0.780 %; P 0.132 %; K 0.730 %; Na 0.035 %; Fe 0.075 %; Zn 600 μg/g; Cu 76.67 μg/g **vitamins:** vitamin C 0.273 %	Sundriyal & Sundriyal 2001
					antioxidants: pulp: phenolics 32.78 GAE μg/mg extract (methanol solvent), 16.86 GAE μg/mg extract (acetone solvent), 20.13 GAE μg/mg extract (aqueous solvent); flavonoids (of dry extract) 71.67 RE μg/mg (methanol solvent), 42.33 RE μg/mg (acetone solvent), 53 RE μg/mg (aqueous solvent); flavonols (of extract) 85.6 RE μg/mg (methanol solvent), 86.41 RE μg/mg (acetone solvent), 86.25 RE μg/mg (aqueous solvent); 4.4 μg TE/mg FRAP (methanol solvent), 2.1 μg TE/mg FRAP (acetone solvent), 5.2 μg TE/mg FRAP (aqueous solvent) **minerals:** Ca 4,250 mg/100 g; Mg 10,930 mg/100 g; K 119,500 mg/100 g; Na 7,580 mg/100 g; Fe 1,090 mg/100 g	Mann et al. 2016

					minerals: pulp: Ca 169 mg/100 g; K 137 mg/100 g; P 177 mg/100 g; Fe 100 mg/100 g **vitamins:** pulp: vitamin C 178 mg/100 g	Hossain et al. 2017
13	*Baccaurea macrophylla* (Müll.Arg.) Müll.Arg.	Phyllanthaceae	E Asia, Malaysia, Sumatra	pulp	**antioxidants:** IC_{50} 66.00 µg/mL DPPH (fresh pulp); IC_{50} 14.00 µg/mL DPPH (fresh peel); phenolics: 5.81 mg GAE/g (fresh pulp); 151.33 mg GAE/g (fresh peel)	Tisadondilok & Senawong 2018
14	*Bombax ceiba* L.	Malvaceae	E, SE Asia, Thailand	roots, leaves, flowers, seeds, gum	**antioxidants:** flowers: β-carotene 800 mg/100 g fw; fresh tissue: lycopene 0.19 mg/100 g; anthocyanin 3.89 mg/100 g; phenol 13.708 mg/100 g **minerals:** Ca 273 mg/100 g dw; K 180 mg/100 g dw; Na 1,039 mg/100 g dw; P 40 mg/100 g dw; Fe 40 mg/100 g dw **vitamins:** flowers: vitamin C 7.82 mg/100 g fw; vitamin A 133,333 IU/100 g fw; retinol 400 mg/100 g fw	Bhogaonkar et al. 2016
					minerals: calyces: Ca 95 mg/100 g; Mg 64 mg/100 g; P 41 mg/100; flowers: Ca 92.25 mg/100 g; Mg 54.24 mg/100 g; P 49 mg/100 g; roots: Ca 93 mg/100 g; seeds: I 92.3 mg/100 g; leaves (dw): Na 19.07 mg/100 g; K 153.66 mg/100 g; Ca 177 mg/100 g	Panwar et al. 2020

	antioxidants: leaves: IC_{50} 0.114 mg/mL DPPH (aqueous extract); IC_{50} 0.022 mg/mL DPPH (50% ethanol extract); IC_{50} 0.012 mg/mL DPPH (95% ethanol extract); IC_{50} 0.096 mg/mL ABTS (aqueous extract); IC_{50} 0.018 mg/mL ABTS (50% ethanol extract); IC_{50} 0.009 mg/mL ABTS (95% ethanol extract); 30.04 mg TE/g FRAP (aqueous extract); 113.20 mg TE/g FRAP (50% ethanol extract); 94.55 mg TE/g FRAP (95% ethanol extract); phenolics: 0.09 mg GAE/g (aqueous extract); 1.01 mg GAE/g (50% ethanol extract); 1.67 mg GAE/g (95% ethanol extract); flavonoids: 1.34 mg QE/g (aqueous extract); 13.22 mg QE/g (50% ethanol extract); 16.87 mg QE/g (95% ethanol extract) flowers: IC_{50} 0.025 mg/mL DPPH (aqueous extract); IC_{50} 0.019 mg/mL DPPH (50% ethanol extract); IC_{50} 0.024 mg/mL DPPH (95% ethanol extract); IC_{50} 0.019 mg/mL ABTS (aqueous extract); IC_{50} 0.037 mg/mL ABTS (50% ethanol extract); IC_{50} 0.029 mg/mL ABTS (95% ethanol extract); 112.14 mg TE/g FRAP (aqueous extract); 102.5 mg TE/g FRAP (50% ethanol extract); 349 mg TE/g FRAP (95% ethanol extract); phenolics: 0.82 mg GAE/g (aqueous extract); 1.15 mg GAE/g (50% ethanol extract); 2.73 mg GAE/g (95% ethanol extract); flavonoids: 8.71 mg QE/g (aqueous extract); 16.33 mg QE/g (50% ethanol extract); 28.25 mg QE/g (95% ethanol extract)	Kriintog & Katisart 2020

15	*Borassus flabellifer* L.	Arecaceae	E Asia, Thailand	pulp, sap, seeds, seedlings, leaves, apical buds, inflorescence	**minerals:** Ca 8.76 mg/100 g (pulp powder) **vitamins:** vitamin C 16 mg/100 g	Vijayakumaji et al. 2014
					antioxidants: IC_{50} 40.19 μg/mL DPPH (methanol extract); IC_{50} 21.80 μg/mL DPPH (ascorbic acid); IC_{50} 30.92 μg/mL H_2O_2 (methanol extract); IC_{50} 18.85 μg/mL H_2O_2 (ascorbic acid)	Jamkhande et al. 2016
16	*Bouea macrophylla* Griff.	Anacardiaceae	SE Asia	pulp, leaves	**antioxidants:** juice: phenolics 372.35 mg GAE/g dw; fruit: lutein 0.457 mg/100 g, cryptoxanthin 0.155 mg/100 g, γ-carotene 0.052 mg/100 g, β-carotene 0.301 mg/100 g	Khoo et al. 2016
					antioxidants: phenolics 30.84 mg GAE/g (hexane extract); quercetin 4.36 mg QE/g (hexane extract); reducing power 5.62 mg $FeSO_4$ equivalent/g (ethanol extract)	Hardinsyah et al. 2019
17	*Breynia fruticosa* (L.) Müll.Arg.	Phyllanthaceae	E, SE Asia, Thailand, Vietnam	shoots	no data	-
18	*Buchanania cochinchinensis* (Lour.) M.R.Almeida	Anacardiaceae	E, SE Asia, Thailand	pulp, seed	**minerals:** fruit: P 53.3 mg/100 g dw; K 229.2 mg/100 g dw; Cu 0.21 mg/100 g dw; Fe 4.49 mg/100 g dw; Mg 61.89 mg/100 g dw; Zn 0.88 mg/100 g dw; Ca 61.54 mg/100 g dw; Na 21.22 mg/100 g dw	Mundaragi et al. 2017[a]

					minerals: seeds: P 593 mg/100 g; Zn 3.32 mg/100 g; B 0.6 mg/100 g; Ca 70 mg/100 g; Cu 1.15 mg/100 g; Fe 4.80 mg/100 g; Mg 275 mg/100 g; Mn 1.60 mg/100 g	Mundaragi et al. 2017[b]
					antioxidants: phenolics 10–93 mg GAE/g; flavonoids 30–87 mg QE/g (of extract)	Dixit et al. 2019
19	*Carissa spinarum* L.	Apocynaceae	SE Asia, India, Thailand	pulp, roots	**antioxidants:** phenolics 5.31 mg TAE/g fw; flavonoids 0.44 mg QE/100 g fw; DPPH = 34.45 % (fw); FRAP = 58.63 % (fw); anthocyanin 54.03 mg C3G/100 g fw **minerals:** Ca 29 mg/100 g fw; Fe 3.45 mg/100 g fw; P 32.1 mg/100 g fw	Chauhan et al. 2015
					minerals: fruit: P 16.1 mg/100 g dw; K 217.5 mg/100 g dw; Cu 0.31 mg/100 g dw; Fe 7.42 mg/100 g dw; Mg 75.34 mg/100 g dw; Zn 0.57 mg/100 g dw; Ca 31.54 mg/100 g dw; Na 33.77 mg/100 g dw	Mundaragi et al. 2017[a]
20	*Carissa carandas* L.	Apocynaceae	E Asia, India, Bangladesh	pulp	**minerals:** Ca 21 mg/100 g	Kumar et al. 2013
					antioxidants: unripe fruit: 0.85 mg AEAC/g DPPH; 25.9 µmol FeSO4/g FRAP; phenolics 1.25 mg GAE/g; anthocyanin 0.33 mg/l; fully ripe fruit: 2.42 mg AEAC/g DPPH; 37.81 µmol FeSO4/g FRAP; phenolics 4.67 mg GAE/g; anthocyanin 54.80 mg/L **vitamins:** unripe fruit: vitamin C 300.75 mg/100 g; fully ripe fruit: vitamin C 180.40 mg/100 g	Pewlong et al. 2014

					antioxidants: phenolics 324.96 mg GAE/g (ethanol extract), 228.23 mg GAE/g (aqueous extract); flavonoids 428.25 mg RE/g (ethanol extract), 352.06 mg RE/g (aqueous extract)	Singh et al. 2020[b]
21	*Cassia fistula* L.	Leguminosae	SE Asia	pods, pulp, flowers, leaves	**antioxidants:** phenolics: leaves: 19.0 g/100 g of extract; pulp: 2.12 g/100 g of extract; flowers: 6.52 g/100 g of extract	Siddhuraju 2002
					antioxidants: phenolics 11 mg GAE/g dw (young leaves), 12 mg GAE/g dw (old leaves), 44 mg GAE/g dw (flower buds), 32 mg GAE/g dw (flowers), 54 mg GAE/g dw (pods) flavonoids 9 mg QE/g dw (young leaves), 6 mg QE/g dw (old leaves), 8 mg QE/g dw (flower buds), 8 mg QE/g dw (flowers), 14 mg QE/g dw (pods) antioxidant activity 98 μmol TE/g dw (young leaves), 102 μmol TE/g dw (old leaves), 893 μmol TE/g dw (flower buds), 453 μmol TE/g dw (flowers), 992 μmol TE/g dw (pods) antioxidant activity 51 μmol Fe (II)/g dw (young leaves), 64 μmol Fe (II)/g dw (old leaves), 380 μmol Fe (II)/g dw (flower buds), 317 μmol Fe (II)/g dw (flowers), 811 μmol Fe (II)/g dw (pods) proanthocyanidins 2 mg CCE/g dw (young leaves), 3 mg CCE/g dw (old leaves), 20 mg CCE/g dw (flower buds), 14 mg CCE/g dw (flowers), 21 mg CCE/g dw (pods)	Bahorun et al. 2011
22	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	SE Asia, Thailand	seed, pericarp	**antioxidants:** pericarp: phenolics 46.8 mg GAE/g	Prakash et al. 2012

23	*Citrus lucida* (Scheff.) Mabb.	Rutaceae	SE Asia, Thailand	pulp, flowers	**antioxidants:** antioxidant capacity 25.34 mg BHAE/g fw (ethanolic extract); phenolics 34.51 mg GAE/g fw (ethanolic extract); 4.78 mg BHAE/g fw (water extract); phenolics 12.87 mg GAE/g fw (water extract)	Tangkanakul et al. 2005
					antioxidants: phenolics 2.80 g/100 g; flavonoids 86.26 mg/100 g; 8.35 % DPPH scavenging activity; 90.67 mmol $FeSO_4$/100 g dw FRAP; 20.43 % β-carotene bleaching activity	Somdee et al. 2016
24	*Clausena lansium* (Lour.) Skeels	Rutaceae	E Asia, China, Vietnam	pulp, leaves	no data	-
25	*Cosmos caudatus* Kunth	Compositae	Pantropical, but naturalized in Thailand	leaves, tops	**antioxidants:** DPPH radical scavenging activity 86.85 % (neutralization of DPPH radical); DPPH radical scavenging activity 98.56 % (superoxide dismutase activity); phenolics 60.56 mg of GAE/g	Rafat et al. 2010
					antioxidants: total flavonoids 52.19 mg/100 g fw; quercetin 51.28 mg/100 g fw; kaempferol 0.90 mg/100 g fw; total phenolic acids 10.92 mg/100 g fw; chlorogenic acid 4.54 mg/100 g fw; caffeic acid 3.64 mg/100 g fw; ferulic acid 3.14 g/100 g fw; total phenols 342 mg GAE/100 g fw; anthocyanin 0.78 mg/100 g fw; β-carotene 1.35 mg/100 g fw; total carotenoids 9.55 mg β–carotene equivalents/100 g fw **vitamins:** vitamin C 108.83 mg/100 g fw	Andarwulan et al. 2012

					antioxidants: flavonoids 27.7 mg QE/g dw (70% methanol extract); phenols 1.52 mg GAE/100 g; IC_{50} 21.3 μg/mL DPPH	Bunawan et al. 2014
					antioxidants: β-carotene 3568 μg/100 g; antioxidant capacity 2511.7 mg AEAC/100 g; phenolics 1274 mg GAE/100 g fw; kaempferol 0.9 mg/100 g; quercetin 51.28 mg/100 g **minerals:** K 426 mg/100 g; Ca 270 mg/100 g; P 37 mg/100 g; Mg 50 mg/100 g; Fe 4.6 mg/100 g; Zn 0.9 mg/100 g; Na 4.0 mg/100 g; Cu 0.2 mg/100 g **vitamins:** vitamin C 64.6 mg/100 g; thiamine 0.13 mg/100 g; riboflavin 0.24 mg/100 g	Cheng et al. 2015
26	*Cynometra cauliflora* L.	Leguminosae	SE Asia	seed pods	**antioxidants:** phenolics 847.31 mg GAE/100 g samples (methanol solvent); 98.79 mg GAE/100 g samples (water solvent); 19,397.22 μmol/g samples dw FRAP (methanol solvent); 7,197.22 μmol/g samples dw FRAP (water solvent) **minerals:** Ca 6.14 mg/100 g dw; Zn 0.48 mg/100 g dw; Fe 1.01 mg/100 g dw; Na 0.55 mg/100 g dw	Rabeta & Nur Faraniza 2013
27	*Dialium indum* L.	Leguminosae	E Asia, peninsular Thailand	pulp	**antioxidants:** phenolics 6.74 mg GAE/g dw (hydroethanolic extract); flavonoids 0.02 mg QE/g dw (hydroethanolic extract); 0.84 mg AEAC/g dw (hydroethanolic extract); IC_{50} 179.08 μg/mL DPPH; nitric oxide scavenging ability IC_{50} 96.78 %; hydroxyl radical scavenging ability IC_{50} 362.05 μg/mL	Afolabi et al. 2018

28	*Dillenia obovata* (Blume) Hoogland	Dilleniaceae	SE Asia, Thailand	pulp	no data	-
29	*Dolichandrone spathacea* (L.f.) Seem.	Bignoniaceae	E, SE Asia	pulp, flowers	**antioxidants:** phenolics 17.58 mg GAE/g of extract (flowers)	Chan et al. 2019
					antioxidants: antioxidant activity IC50 15.89 µg/mL **minerals:** relative percent abundance of elements in flowers: K 3.672 %, Ca 0.808 %, Cl 0.396 %, S 0.247 %, P 0.226 %, Fe 0.179 %, Si 0.0914 %, Zn 0.0266 %, Cu 0.0215 %	Mar & Win 2019
30	*Dracontomelon costatum* Blume	Anacardiaceae	E, SE Asia	pulp	no data	-
31	*Dracontomelon dao* (Blanco) Merr. & Rolfe	Anacardiaceae	E, SE Asia, Thailand	pulp, seed, flowers, leaves	**minerals:** freeze-dried samples: Ca 3,067.5 mg/100 g dw; Cl 53 mg/100 g dw; Co 0.01 mg/100 g dw; Fe 18.3 mg/100 g dw; K 666.5 mg/100 g dw; Mg 108.9 mg/100 g dw; Mn 3.23 mg/100 g dw; Na 7.4 mg/100 g dw; Zn 30.1 mg/100 g dw	Majid et al. 1995
32	*Durio kutejensis* (Hassk.) Becc.	Malvaceae	SE Asia	pulp	**minerals:** (of edible portion) P 25 mg/100 g; K 362 mg/100 g; Ca 19 mg/100 g; Mg 19 mg/100 g; Fe 0.7 mg/100 g; Mn 0.5 mg/100 g; Cu 0.32 mg/100 g; Zn 0.73 mg/100 g **vitamins:** (of edible portion) vitamin C 15.9 mg/100 g	Hoe & Siong 1999
					antioxidants: IC_{50} 1.0 µg/mL ABTS (ethyl acetate solvent); IC_{50} 18.2 µg/ml SOD like activity (hexane solvent); IC_{50} 21.5 µg/ml DPPH (ethyl acetate solvent); 0.04 µmol TE/mg (ethyl acetate solvent) TEAC	Arung et al. 2015

33	*Flacourtia inermis* Roxb.	Salicaceae	Native to Malaysia, but cultivated in Thailand	pulp	**antioxidants:** polyphenols 1.28 g GAE/100 g fw; anthocyanin 108 mg C3G equivalents/100 g fw; IC_{50} 66.2 mg/L DPPH (ethyl acetate extract)	Alakolanga et al. 2015
34	*Flacourtia rukam* Zoll. & Moritzi	Salicaceae	SE Asia, China, India, but cultivated in Thailand	shoots, pulp	**antioxidants:** IC_{50} 47.7022 mg/L DPPH (ethanol extract); IC_{50} 33.1702 mg/L DPPH (acetone extract)	Fadiyah et al. 2020
35	*Garcinia cowa* Roxb. Ex Choisy	Clusiaceae	SE Asia, Thailand	pulp, leaves	**antioxidants:** fruits: phenols 74.18 µg GAE/mg; IC_{50} 33.15 µg/mL DPPH **vitamins:** fruits: vitamin C 68.03 mg/100 g	Sarma et al. 2014
36	*Garcinia dulcis* (Roxb.) Kurz	Clusiaceae	SE Asia	pulp	**minerals:** K 64.63 mg/100 g fw; P 7.79 mg/100 g fw; Ca 7.59 mg/100 g fw; Mg 3.85 mg/100 g fw; Na 1.60 mg/100 g fw; Fe 0.31 mg/100 g fw; Zn 0.31 mg/100 g fw; Cu 0.02 mg/100 g fw **vitamins:** vitamin C 6.88 mg AAE/100 g fw	Hamid et al. 2012
					antioxidants: IC_{50} 38.613 µg/mL DPPH (methanol extract); IC_{50} 139.381 µg/mL DPPH (wasbenzene extract)	Santosa & Haresmita 2015
					antioxidants: fruit rind: phenolics 56.52 mg GAE/g (dry extract); flavonoids 84.88 mg RE/g (dry extract)	Gogoi et al. 2017

37	*Garcinia schomburgkiana* Pierre	Clusiaceae	Thailand	pulp, leaves	**minerals:** fruit: Ca 17 mg/100 g fw; P 7.0 mg/ 100 g fw; leaves: Ca 103 mg/100 g fw; P 8 mg/100 g fw **vitamins:** fruit: vitamin A 431 IU/100 g fw; riboflavin 0.04 mg/100 g fw; vitamin C 5.0 mg/100 g fw; leaves: vitamin A 431 IU/100 g fw; thiamine 0.01 mg/100 g fw; riboflavin 0.04 mg/100 g fw; niacin 0.02 mg/100 g fw; vitamin C 5.0 mg/100 g fw **antioxidants:** EC_{50} 6,952.48 µg extract/mg DPPH; 2.60 mmol/L FRAP reducing ability; phenolics 210 µg GAE/mg (dry extract)	FAO 2001 Nanasombat et al. 2012
38	*Gnetum gnemon* L.	Gnetaceae	SE Asia, Thailand	leaves, seeds, pulp, peel, sap	**antioxidants:** seed flour: phenolics 12.6 mg GAE/100g (aqueous extract), 15.1 mg GAE/100g (ethanol extract); tannins 16.1 mg CE/100 g (aqueous extract), 35.6 mg CE/100 g (ethanol extract); flavonoids 81.6 mg CE/100 g (aqueous extract), 709 mg CE/100 g (methanol extract); 0.98 mmol Fe (II)/100 g FRAP (aqueous extract), 0.61 mmol Fe (II)/100 g FRAP (ethanol extract); inhibition of DPPH = 19.7 % (aqueous extract), 48.9 % (ethanol extract) **minerals:** seed flour: Ca 157 mg/100 g; Na 14.0 mg/100 g; Cu 1.07 mg/100 g; Mg 26.4 mg/100 g; Zn 4.12 mg/100 g	Bhat & Binti Yahya 2014

					antioxidants: leaves: β-carotene 404.52 μg/100 g; lutein 6,731.17 μg/100 g; polyphenols 253.45 mg GAE/100 g; anthocyanidins 0.11 mg/100 g **minerals:** leaves: Ca 35.15 mg/100 g fw; K 297.29 mg/100 g fw; P 72.70 mg/100 g fw; Mg 28.00 Fe 0.40 mg/100 g fw **vitamins:** leaves: vitamin C 109.43 mg AAE/100 g; vitamin E 1.33 mg/100 g	Kongkachuichai et al. 2015
					antioxidants: IC_{50} 45.72 mg/mL DPPH (ethanol extract)	Phukan et al. 2016
					minerals: leaves: K 1,777.80 mg/100 g dw; Na 158.52 mg/100 g dw; Ca 204.90 mg/100 g dw; P 240.02 mg/100 g dw; Mg 224.60 mg/100 g dw; Mn 9.67 mg/100 g dw; Fe 4.99 mg/100 g dw; Zn 3.09 mg/100 g dw; Cu 0.67 mg/100 g dw	Ainul Asyira et al. 2016
					antioxidants: seed endosperm: IC50 1549.90 mg/L DPPH (95% ethanol solvent); phenolics 1.40 mg GAE/mL	Saraswaty et al. 2017
39	*Grewia asiatica* L.	Malvaceae	E Asia, Thailand	pulp	**antioxidants:** phenolics 288 mg GAE/100 g; flavonoids 178 mg CE/100 g; anthocyanins 72 C3G mg/100 g; DPPH radical scavenging activity = 85 %; β-carotene-linoleic acid assay = 89 % inhibition	Siddiqi et al. 2013

					antioxidants: IC_{50} 257.66 µg/mL DPPH; 4.14 GAE/g FRAP dw; total antioxidant activity 4.88 mg/kg; IC_{50} 134.33 µg/mL ABTS; phenolics 294.35 mg GAE/g dw; flavonoids 116.95 mg QE/g dw **minerals:** Na 17.3 mg/100 g; K 372 mg/100 g; Ca 136 mg/100 g; Co 0.99 mg/100 g; Zn 1.44 mg/100 g; Fe 140.8 mg/100 g; Ni 2.61 mg/100 g; P 24.2 mg/100 g **vitamins:** vitamin A 16.11 mg/100 g; vitamin C 4.38 mg/100 g; thiamine 0.02 mg/100 g; riboflavin 0.26 mg/100 g; niacin 0.82 mg/100 g	Mehmood et al. 2020
40	*Gymnema inodorum* (Lour.) Decne	Apocynaceae	SE Asia, Thailand	leaves	**antioxidants:** carotenes 1.31 mg/100 g; xanthophylls 1.07 mg/100 g; tannins 11.1 mg/100 g; phenolics 188 mg/100 g **vitamins:** vitamin C 19.3 mg/100 g; vitamin E 0.0301 mg/100 g	Chanwitheesuk et al. 2005
					minerals: Mg 233.35 mg/100 g dw; Si 194.86 mg/100 g dw; P 217.17 mg/100 g dw; S 632.54 mg/100 g dw; Cl 1,234.04 mg/100 g dw; K 30,211.3 mg/100 g dw; Ca 60.912.36 mg/100 g dw; Mn 654.17 mg/100 g dw; Fe 2,658.55 mg/100 g dw; Zn 543.65 mg/100 g dw	Sukum et al. 2019
					antioxidants: IC50 406.59 µg/mL DPPH; 24 µg AEAC/mg FRAP (dry extract); 28.06 µg TE/mg FRAP (dry extract)	Dunkhunthod et al. 2021

41	*Gynura bicolor* (Roxb. ex Willd.) DC.	Compositae	E, SE Asia, Thailand	leaves, shoots	**antioxidants:** polyphenols 9.61 mg GAE/g dw; flavonoids 56.07 mg QE/g dw; flavonols 7.59 mg QE/g dw; anthocyanidins 21.65 units/g dw	Chao et al. 2014
					minerals: K 2,080 mg/100 g dw; Na 7.26 mg/100 g dw; Ca 1,850 mg/100 g dw; P 310 mg/100 g dw; Mg 620 mg/100 g dw; Cu 0.85 mg/100 g dw; Fe 6.26 mg/100 g dw; Zn 1.19 mg/100 g dw; Mn 6.59 mg/100 g dw	Wang et al. 2015
					antioxidants: EC_{50} 44.35 µg/mL DPPH; EC_{50} 36.36 µg/mL ABTS; reduce power EC_{50} 36.92 µg/mL	Qiu et al. 2018
					antioxidants: anthocyanins: cyanidin 201 mg G3G/100 g dw (water solvent); kuromanin 29 mg G3G /100 g; malvidin 263 mg G3G/100 g; pelargonidin 305 mg G3G/100 g dw (water solvent); peonidin 58 mg G3G/100 g dw (water solvent); petunidin 191 mg G3G/100 g dw (water solvent) carotenoids: lutein 215 mg LE/100 g dw (water solvent); zeaxanthin 71 mg LE/100 g dw (water solvent) flavonoids: apigenin 160 mg QE/100 g dw (water solvent); epicatechin 160 mg QE/100 g dw (water solvent); kaempferol 57 mg QE/100 g dw (water solvent); myricetin 127 mg QE/100 g dw (water solvent); narigenin 93 mg QE/100 g dw (water solvent); quercetin 221 mg QE/100 g dw (water solvent); rutin 131 mg QE/100 g dw (water solvent)	Do et al. 2020

					minerals: Mn 3.47 mg/100 g fw; Zn 0.88 mg/100 g fw; P 30.94 mg/100 g fw; Ca 163.39 mg/100 g fw; Mg 117.5 mg/100 g fw; K 617.3 mg/100 g fw; Fe 4.94 mg/100 g fw; Cu 1.03 mg/100 g fw; Na 6.26 mg/100 g fw **vitamins:** thiamine 0.08 mg/100 g fw; riboflavin 0.17 mg/100 g fw; niacin 0.41 mg/100 g fw; vitamin C 12.96 mg/100 g fw; vitamin E 0.06 mg/100 g fw	
42	*Gynura procumbens* (Lour.) Merr.	Compositae	E, SE Asia, W Africa, Thailand	leaves	**antioxidants:** carotenoids 53.20 μg/g dw	Kaewseejan et al. 2012
					antioxidants: leaves: phenolics 24.36 mg GAE/g dw (ethyl acetate fraction); flavonoids 17.33 mg CE/g dw (ethyl acetate fraction); IC_{50} 0.22 mg/mL DPPH (ethyl acetate fraction); IC_{50} 0.06 mg/mL ABTS (ethyl acetate fraction); IC_{50} 0.01 mg/mL •OH scavenging (ethyl acetate fraction); IC_{50} 0.03 mg/mL H_2O_2 scavenging (ethyl acetate fraction)	Kaewseejan & Siriamornpun 2015
43	*Gynura pseudochina* (L.) DC.	Compositae	E, SE Asia, W Africa, Thailand	leaves	no data	-
44	*Chrysophyllum roxburghii* G.Don	Sapotaceae	SE Asia, tropical areas around the world	pulp	**minerals:** P 46.8 mg/100 g fw; K 586.5 mg/100 g fw; Ca 56.3 mg/100 g fw; Mg 21.2 mg/100 g fw; S 79.8 mg/100 g fw; Fe 3.0 mg/100 g fw; Mn 3.4 mg/100 g fw; Zn 0.2 mg/100 g fw; B 0.3 mg/100 g fw; Cu 0.3 mg/100 g fw; Na 4.2 mg/100 g fw; Cl 53.2 mg/100 g fw; Se 0.3 mg/100 g fw; Si 14.1 mg/100 g fw	Barthakur & Arnold 1991[a]

					antioxidants: carotenoids: violaxanthine 3.13 mg/100 g fw; neoxanthin 11.33 mg/100 g fw; lutein 0.04 mg/100 g fw; β-carotene 0.14 mg/100 g fw	Chandrika et al. 2005
45	*Lansium parasiticum* (Osbeck) K.C.Sahni & Bennet	Meliaceae	SE Asia, Thailand	pulp	**minerals:** Ca 20.0 mg/100 g fw; P 30.0 mg/100 g fw **vitamins:** vitamin A 13.0 IU/100 g fw; thiamine 89 μg/100 g fw; riboflavin 124 μg/100 g fw; vitamin C 1.0 mg/100 g fw	Tilaar et al. 2008
46	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae	SE Asia, Thailand	pulp, leaves	**antioxidants:** leaves: 422.42 mg GAE/100 g dw extract; flavonoids 350 mg QE/100 g dw extract; tannins 233.3 mg GAE/100 g dw extract; IC_{50} 31.62 μg/mL DPPH	Hasan et al. 2017
47	*Lepisanthes fruticosa* (Roxb.) Leenh.	Sapindaceae	SE Asia, Thailand	pulp, seeds	**antioxidants:** pulp: IC_{50} 0.207 mg/mL DPPH (ethanol extract); seeds: IC_{50} 0.178 mg/mL DPPH (ethanol extract)	Salahuddin et al. 2020
48	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	Indian subcontinent but naturalized in Thailand	pulp, shoots, leaves, flowers, flower buds, seeds	**minerals:** Fe 10.7 mg/100 g dw; Ca 62.0 mg/100 g dw; Zn 5.80 mg/100 g dw; Cu 2.18 mg/100 g dw; P 1,050 mg/100 g dw; Mg 330 mg/100 g dw	Kamel & Blackman 1982
					antioxidants: dried pulps: phenolics 28.04 μg GAE/mg of extract (chloroform solvent); 201.12 μmol TE/mg of extract DPPH (hexane solvent)	Supriatno & Lelifajri 2002

					minerals: fruits of variety *amara*: Cu 0.9 mg/100 g; Fe 34.1 mg/100 g; Mg 27.38 mg/100 g; Mn 2.34 mg/100 g; Ca 99.78 mg/100 g; Zn 9.52 mg/100 g **vitamins:** fruits of variety amara: vitamin A 0.0001 μg/100 g; thiamine 0.7692 mg/100 g; riboflavin 0.2061 mg/100 g; niacin 3.1282 mg/100 g; vitamin C 0.083 mg/100 g	Jaysingrao & Sunil 2014
					minerals: pulp: Ca 14 mg/100 g; K 160 mg/100 g; Mg 14 mg/100 g; Zn 0.2 mg/100 g **vitamins:** pulp: thiamine 0.05 mg/100 g; riboflavin 0.01 mg/100 g; niacin 0.20 mg/100 g; vitamin E 1.00 mg/100 g; vitamin C 205.00 mg/100 g	Manikandaselvi et al. 2016
49	*Mangifera foetida* Lour.	Anacardiaceae	SE Asia, Thailand	pulp, seed	**antioxidants:** fruit: 9.3 mmol Fe (II)/100 g dw FRAP; 4.5 mg TE/100 g dw TEAC; 813.7 mg GAE/100 g dw total reducing; flavonoids 7.8 g CE/100 g dw; carotenoids 649.9 μg β-carotene/100 g dw **vitamins:** vitamin C 136.8 mg/100 g dw	Tyug et al. 2010
					antioxidants: phenolics 2,917.92 mg/100 g; flavonoids 282.88 mg/100 g; scavenging activity IC_{50} 43.22 mg/mL **vitamins:** vitamin C 122.13 mg/100 g	Mirfat et al. 2016
50	*Mangifera laurina* Blume	Anacardiaceae	E Asia	pulp	**antioxidants:** phenolics 144.33 mg/100 g; flavonoids 176.71 mg/100 g; scavenging activity IC_{50} 13.32 mg/mL **vitamins:** vitamin C 135.74 mg/100 g	Mirfat et al. 2016
51	*Mangifera odorata* Griff.	Anacardiaceae	SE Asia	pulp, seed flour	**antioxidants:** pulp: phenolics 257.17 mg/100 g; flavonoids 202.33 mg/100 g; scavenging activity IC_{50} 20.16 mg/mL **vitamins:** pulp: vitamin C 47.32 mg/100 g	Mirfat et al. 2016

					antioxidants: pulp: 2.21 mmol/kg dw DPPH; 88.30 mmol/kg dw ABTS; 0.38 mmol/kg FRAP; total soluble polyphenols 0.569 g/100 g dw **vitamins:** pulp: thiamine 0.072 mg/100 g dw; riboflavin 0.976 mg/100 g dw; niacin 3.292 mg/100 g dw; niacinamide 1.40 mg/100 g dw; pyridoxine 0.862 mg/100 g dw	Barbosa Gámez et al. 2017
					antioxidants: seed kernel: total carotene content 60 mg/100 g dw; β-carotene 0.05 mg/100 g dw; α-tocopherol 0.21 mg/100 g dw **minerals:** K 875.69 mg/100 g dw; P 165.50 mg/100 g dw; Ca 141.48 mg/100 g dw; Mg 166.88 mg/100 g dw; S 43.03 mg/100 g dw; Na 10.56 mg/100 g dw; Mn 1.09 mg/100 g dw; Fe 1.08 mg/100 g dw; Zn 1.55 mg/100 g dw; B 0.87 mg/100 g dw **vitamins:** vitamin C 2.62 mg/100 g dw	Lasano et al. 2019
					antioxidants: phenolics 12.11 mg GAE/g dw (flesh), 89.87 mg GAE/ g dw (seed); flavonoids 9.07 mg CE/g dw (flesh), 15.35 mg CE/g dw (seed); carotenoids 52.07 mg β-carotene/g dw (flesh), 26.52 mg β-carotene/g dw (seed); EC_{50} 12.00 μg/mL DPPH (seed); 12.20 μmol ferric reduction to ferrous/g dw (flesh), 201.24 μmol ferric reduction to ferrous/g dw (seed); 8.52 mg AEAC/g dw (flesh) ABTS, 101.91 mg AEAC/g dw (seed) ABTS	Nur et al. 2019
52	*Markhamia stipulata* (Wall.) Seem.	Bignoniaceae	SE Asia	shoots, flowers	**antioxidants:** content of phenolic glycosides	Kanchanapoom et al. 2002

53	*Melientha suavis* Pierre	Opiliaceae	SE Asia, Thailand	leaves, inflorescences, pulp	**antioxidants:** leaves: tannin 53 mg/100 g; phytate 21 mg/100 g **vitamins:** leaves: vitamin C 168 mg/100 g	Somsub et al. 2008
					antioxidants: IC_{50} 900 µg/mL DPPH (water extract); IC_{50} 2.5 µg/mL FRAP (ethyl acetate extract); phenolics 1,978 mg GAE/100 g dw (methanol extract); flavonoids 459.54 mg CE/100 g dw (methanol extract)	Charoenchai et al. 2015
					minerals: Ca 110 mg/100 g; P 80 mg/100 g **vitamins:** vitamin C 114 mg/100 g	Vu & Nguyen 2017
54	*Mesua ferrea* L.	Calophyllaceae	E Asia, Thailand	leaves, seedss, pulp	**antioxidants:** leaves: IC_{50} 31.7 mg/mL DPPH;	Keawsa-ard & Kongtaweelert 2012
55	*Nephelium ramboutan-ake* (Labill.) Leenh.	Sapindaceae	SE Asia, Thailand	pulp, seed	**antioxidants:** phenolics: 433.78 mg GAE/100 g; antioxidant capacity 74.77 %	Ikram et al. 2009
					vitamins: pulp: vitamin C 18.9 mg/100 g	Djuita et al. 2017
56	*Neptunia oleracea* Lour.	Leguminosae	S[t] America, naturalized in Asia	leaves, stems, pods	**antioxidants:** carotenes 3.18 mg/100 g; xanthophylls 1.06 mg/100 g; tannins 21.0 mg/100 g; phenolics 104 mg/100 g **vitamins:** vitamin C 12.9 mg/100 g; vitamin E 0.0066 mg/100 g	Chanwitheesuk et al. 2005
					minerals: Ca 3.87 mg/100 g; Fe 0.53 mg/100 g; P 0.07 mg/100 g **vitamins:** vitamin C 14.55 mg/100 g; thiamine 0.12 mg/100 g; riboflavin 0.14 mg/100 g; niacin 3.2 mg/100 g	Irawan et al. 2006

					antioxidants: IC_{50} 35.45 µg/mL DPPH (leaf), IC_{50} 29.72 µg/mL DPPH (stem); α-glucosidase inhibition activity: 19.09 µg/mL (leaf), 19.74 µg/mL (stem); phenolics 40.88 mg GAE/g dw (leaf), 21.21 mg GAE/g dw (stem)	Lee et al. 2014
					minerals: K 3,309.50 mg/100 g dw; Na 251.33 mg/100 g dw; Ca 381.42 mg/100 g dw; Mg 201.00 mg/100 g dw; P 405.92 mg/100 g dw; Cu 2.97 mg/100 g dw; Zn 10.53 mg/100 g dw; Mn 14.23 mg/100 g dw	Saupi et al. 2015
					antioxidants: tannins 0.63 mg TAE/g fw; flavonoids 0.97 mg QE/g fw; 2,583.29 mg AEAC/g fw ABTS; 44.96 mg AEAC/g fw DPPH; 16.86 mg AEAC/g fw H_2O_2 scavenging; 464.97 mg AEAC/g fw FRAP	Kumar & Chaiyasut 2017
57	*Ocimum americanum* L.	Lamiaceae	E Asia, tropical Africa, Thailand	leaves, seeds	**antioxidants:** total flavonoids 7.22 mg/100 g fw; luteolin 2.12 mg/100 g; quercetin 1.89 mg/100 g fw; apigenin 0.74 mg/100 g fw; kaempferol 2.47 mg/100 g fw; total phenolic acids 2.23 mg/100 g fw; chlorogenic acid 0.32 mg/100 g fw; caffeic acid 2.03 mg/100 g fw; ferulic acid 0.16 mg/100 g fw; total phenols 86.89 mg GAE/100 g fw; anthocyanin 0.11 mg/100 g fw; β-carotene 1.56 mg/100 g fw; total carotenoids 7.35 mg β-carotene equivalents/100 g fw **vitamins:** vitamin C 146.37 mg/100 g fw	Andarwulan et al. 2012

	antioxidants: phenols 1.54 mg GAE/g dw; flavonoids 9.26 mg/g dw; alkaloids 60.7 mg/g dw; saponins 114.7 mg/g dw; tannins 4.70 mg/kg of gallic acid standard; lycopene 0.36 mg/100 g dw; β-carotene 65.52 mg/100 g dw; β-cryptoxanthin 0.14 mg/100 g dw **vitamins:** vitamin C 42.89 mg/100 g dw; thiamine 69.5 mg/100 g dw; retinol 84.09 mg/100 g dw; tocopherol 0.56 mg/100 g dw	Karau et al. 2015
	antioxidants: leaves: total phenolics 94.25 mg GAE/g (water extract), 57.72 mg GAE/g (ethyl acetate extract); total flavonoids 6.25 mg RE/g (water extract), 34.82 mg RE/g (methanol extract); flavanols 1.42 mg CE/g (water extract), 8.30 mg CE/g (ethyl acetate extract); phenolic acids 31.10 mg GAE/g (water extract), 11.97 mg GAE/g (methanol extract); tannins 1.32 mg CE/g (water extract), 11.36 mg CE/g (ethyl acetate extract); saponins 110.15 mg QE/g (water extract), 206.58 mg QE/g (ethyl acetate extract); antioxidant activity: 232.61 mg TE/g DPPH (water extract), 73.67 mg TE/g DPPH (methanol extract); 189.13 mg TE/g ABTS (water extract), 86.87 mg TE/g (methanol extract); 494.56 mg TE/g CUPRAC (water extract), 193.53 mg TE/g CUPRAC (methanol extract); 342.39 mg TE/g FRAP (water extract), 121.82 mg TE/g FRAP (methanol extract); metal chelating: 14.33 mg EDTAE/g (water extract), 26.44 mg EDTAE/g (ethyl acetate extract)	Zengin et al. 2019

					phosphomolybdenum 1.52 mmol TE/g (water extract), 2.49 mmol TE/g (ethyl acetate extract) **minerals:** Ca 41.01 mg/100 g; Fe 1.596 mg/100 g; Na 1.162 mg/100 g; K 18.20 mg/100 g; Mn 0.112 mg/100 g; Zn 0.122 mg/100 g	Mustafa & El-kamali 2019
58	*Oenanthe javanica* (Blume) DC.	Apiaceae	E, SE Asia, Thailand	leaves, stems, roots, seeds	**antioxidants:** phenolics 7.41 mg TAE/100 g fw	Huda-Faujan et al. 2009
					antioxidants: DPPH radical scavenging activity = 56.87 % (neutralization of DPPH radical); superoxide dismutase activity = 73.51 %; phenolics 38.75 mg of GAE/g	Rafat et al. 2010
					antioxidants: β-carotene 1,687.11 μg/100 g; lutein 7,439.11 μg/100 g; polyphenolics 239.23 mg GAE/100 g **minerals:** Ca 133.07 mg/100 g fw; K 414.52 mg/100 g fw; P 60.55 mg/100 g fw; Mg 29.99 mg/100 g fw; Fe 1.35 mg/100 g fw **vitamins:** vitamin C 3.29 AAE/100 g; vitamin E 0.83 mg/100 g	Kongkachuichai et al. 2015
					minerals: P 43.5 mg/100 g fw; K 1,291.3 mg/100 g fw; Ca 170.2 mg/100 g fw; Mg 46.4 mg/100 g fw; Na 2.2 mg/100 g fw; Fe 7.0 mg/100 g fw; Mn 8.4 mg/100 g fw; Zn 14.0 mg/100 g fw; Cu 0.06 mg/100 g fw	Punchay et al. 2020
59	*Parkia speciosa* Hassk.	Leguminosae	SE Asia, peninsular Thailand, E Asia	leaves, pods, seeds, inflorescence	**antioxidants:** phenolics 14.16 mg GAE/g dw; flavonoids 5.28 mg RE/g dw; IC_{50} 74.37 μg/mL DPPH	Balaji et al. 2015

					antioxidants: flavonoids 5.28 mg RE/g dw (pods), 20.3 mg RE/g dw (seeds); phenolics 1,557.6 mg GAE/g (aqueous extract), 2,464.3 mg GAE/g (methanol extract); 7,418.3 μmol trolox/g DPPH (aqueous extract), 5,936.9 μmol trolox/g DPPH (methanol extract); 1,617.3 μmol trolox/g FRAP (aqueous extract), 1,898.0 μmol trolox/g FRAP (methanol extract) **minerals:** Ca 108.0–265.1 mg/100 g; Fe 2.2–2.7 mg/100 g; P 115.0 mg/100 g; K 341.0 mg/100 g; Mg 29.0 mg/100 g; Cu 3.67 mg/100 g; Zn 0.82 mg/100 g **vitamins:** seeds: vitamin C 19.3 mg/100 g; α-tocopherol 4.15 mg/100 g; thiamine 0.28 mg/100 g	Chhikara et al. 2018
					antioxidants: flavonoids 12.4 mg QE/g dw; phenolics 26.3 mg GAE/g dw; DPPH free radical scavenging activity = 66.29 %; 522.1 μmol of Fe (II)/g FRAP; IC_{50} 91.5 μg/mL FRAP; IC50 86.7 μg/mL (DPPH)	Ghasemzadeh et al. 2018
60	*Phyllanthus emblica* L.	Phyllanthaceae	SE Asia, India	pulp, leaves, seeds	**minerals:** fruit: P 28.2 mg/100 g fw; K 282.0 mg/100 g fw; Ca 27.6 mg/100 g fw; Mg 11.8 mg/100 g fw; S 16.6 mg/100 g fw; Fe 3.3 mg/100 g fw; Mn 1.1. mg/100 g fw; Zn 1.8 mg/100 g fw; B 0.22 mg/100 g fw; Cu 0.28 mg/100 g fw; Na 4.2 mg/100 g fw; Cl 35.5 mg/100 g fw; Se 0.24 mg/100 g fw; Si 23.5 mg/100 g fw	Barthakur & Arnold 1991[b]

					antioxidants: carotenoids 83 μg/100 g; phytosterols 13.08 mg/100 g; phenolics 3,703 mg GAE/100 g; 489 μmol TE/g DPPH; 652 μmol TE/g FRAP; 455 μmol TE/g ORAC **minerals:** Ca 42 mg/100 g; P 21 mg/100 g; Na 13 mg/100 g; K 151 mg/100 g; Mg 13 mg/100 g; Fe 0.16 mg/100 g; Cu 0.04 mg/100 g; Zn 0.14 mg/100 g **vitamins:** vitamin C 575 mg/100 g; vitamin E 0.16 mg/100 g	Judprasong et al. 2013
					minerals: variety Chakaiya: Fe 3.10 mg/100 g; Zn 6.556 mg/100 g; Na 6.937 mg/100 g; K 62.20 mg/100 g; Ca 25.02 mg/100 g **vitamins:** variety Chakaiya: vitamin C 2.83 g/100 g	Parveen & Khatkar 2015
					antioxidants: phenolics 295.94 mg GAE/g; flavonoids 115.01 mg CE/g; 1,106.96 mmol TE/g ABTS; IC_{50} 0.02 mg/mL DPPH; 5,355.89 mmol Fe (II)/g FRAP	Jayathilake et al. 2016
					minerals: Ca 0.05 %; P 0.02 %; Fe 1.2 mg/100 g **vitamins:** vitamin C 600 mg/100 g; niacin 0.2 mg/100 g	Hasan et al. 2016
61	*Pluchea indica* (L.) Less.	Compositae	E Asia, Thailand	leaves, shoots, tops, inflorescences	**antioxidants:** β-carotene 1.70 mg β-carotene equivalents/100 g fw; phenolic acids 28.48 mg/100 g fw; flavonoids 6.39 mg/100 g fw; anthocyanins 0.27 mg/100 g fw; total phenols 0.831 mg GAE/ g fw; 96.4 µmol TE/g fw DPPH; 3.75 µmol TE/g fw ABTS; 81.1 µmol TE/g fw FRAP **minerals:** Ca 251 mg/100 g **vitamins:** vitamin C 0.03 mg/100 g	Suriyaphan 2014

					antioxidants: flavonoids 418.46 mg/100 g	Susylowati & Takarina 2019
					antioxidants: IC_{50} 379.822 µg/mL DPPH; phenolics 3.783 mg GAE/g; 3.284 mg Fe (II)/mL FRAP	Zabidi et al. 2020
62	*Saurauia napaulensis* DC.	Actinidiaceae	E, SE Asia, Thailand	pulp	**antioxidants:** phenolic components	Wang et al. 2008
63	*Sauropus androgynus* (L.) Merr.	Phyllanthaceae	E, SE Asia	leaves, pulps	**antioxidants:** IC_{50} 85 µg/ml DPPH; IC_{50} 350 µg/ml ABTS	Subhasree et al. 2009
					antioxidants: phenols 1.49 mg GAE/g fw; 7.72 µmol TE/g fw DPPH; 1.81 µmol TE/g fw ABTS; 70.6 µmol TE/g fw FRAP; flavonoids 143 mg/100 g fw	Andarwulan et al. 2010
					antioxidants: EC_{50} 179.11 µg/mL DPPH scavenging activity	Phadungkit et al. 2012
					antioxidants: total flavonoids 143 mg/100 g fw; quercetin 4.50 mg/100 g fw; kaempferol 138.14 mg/100 g fw; total phenolics acids 5.12 mg/100 g fw; chlorogenic acid 3.38 mg/100 g fw; caffeic acid 1.13 mg/100 g fw; ferulic acid 1.10 mg/100 g fw; total phenols 138.01 mg GAE/100 g fw; anthocyanin 1.53 mg/100 g fw; β-carotene 1.63 mg/100 g fw; total carotenoids 5.15 mg β-carotene equivalents/100 g fw **vitamins:** vitamin C 190.83 mg/100 g fw	Andarwulan et al. 2012

					antioxidants: leaves: tannins 88.68 mg/100 g; phenolics 2,300.00 mg GAE/100 g; 2,930.00 mg CE/100 g; 576.00 mg chlorogenic acid equivalent/100g; flavonoids 1,530.00 mg/100 g; anthocyanins 82.04 mg/100 g **minerals:** leaves: Mg 664.9 mg/100 g dw; K 45.7 mg/100 g dw; Na 306.3 mg/100 g dw; Ca 84.4 mg/100 g dw; P 61.2 mg/100 g dw; Fe 212.5 mg/100 g dw; Zn 15.9 mg/100 g dw; Mn 25.6 mg/100 g dw; Cu 768.7 mg/100 g dw; Co 0.06 mg/100 g dw **vitamins:** leaves: vitamin A 10,000 IU/100 g edible portion; thiamine 0.48 mg/100 g edible portion; riboflavin 0.32 mg/100 g edible portion; nicotinic acid 2.60 mg/100 g edible portion; vitamin C 247.00 mg/100 g edible portion; vitamin E 0.43 mg/100 g edible portion	Petrus 2013
64	*Sesbania grandiflora* (L.) Pers.	Leguminosae	E, SE Asia	flowers, pods, seeds, leaves, shoots, gum	**antioxidants:** leaves: 25,679 μg β-carotene equivalents/100 g; flowers: 636 μg β-carotene equivalents/100 g **minerals:** leaves: Ca 1,130 mg/100 g; P 80 mg/100 g; Fe 3.9 mg/100 g; flowers: Ca 145 mg/100 g; P 290 mg/100 g; Fe 5.4 mg/100 g; Na 291 mg/100 g; K 1,400 mg/100 g; seeds: 4.5 % ash **vitamins:** leaves: vitamin A 9,000 IU/100 g; thiamine 0.21 mg/100 g; riboflavin 0.09 mg/100 g; niacin 1.2 mg/100 g; vitamin C 169 mg/100 g; flowers: thiamine 0.91 mg/100 g; riboflavin 0.72 mg/100 g; niacin 14.54 mg/100 g; vitamin C 473 mg/100 g	Duke 1983

					antioxidants: phenolics 21.2 g TAE/kg; tannin 13.2 g TAE/kg;	Bhatta et al. 2012
					minerals: Ca 989 mg/100 g dw; K 690 mg/100 g dw; Na 66 mg/100 g dw; P 679 mg/100 g dw; Mg 131 mg/100 g dw; Fe 18 mg/100 g dw	Anitha & Mary Josephine 2014
65	*Solanum spirale* Roxb.	Solanaceae	SE Asia, Thailand	leaves, shoots, pulps	**minerals:** leaves: Ca 0.014 mg/100 g; P 99 mg/100 g; K 23.00 mg/100 g; Na 0.07 mg/100 g; berry: Ca 0.013 mg/100 g; P 102.00 mg/100 g; K 0.64 mg/100 g; Na 0.07 mg/100 g **vitamins:** leaves: vitamin A 42.9 mg/100 g; vitamin C 45.6 mg/100 g; vitamin E 55.7 mg/100 g; berry: vitamin A 34.6 mg/100 g; vitamin C 53.4 mg/100 g; vitamin E 23.00 mg/100 g	Kalita et al. 2014
					antioxidants: 64.14 % inhibition of DPPH (methanol extract); 63.55 % inhibition of superoxide radical (methanol extract); 79.89 % inhibition of hydrxyl radical (methanol extract); phenolics 45.95 mg GAE/g (methanol extract); flavonoids 31.95 mg CE/g (methanol extract)	Boruah & Handique 2014
					antioxidants: berry: phenolics 11.72 mg GAE/g; flavonoids 50.52 μmol RE/g; 38.27 μmol/g ABTS; 52.00 μmol/g DPPH; shoots: phenolics 18.64 mg GAE/g; flavonoids 5.29 μmol RE/g; 29.85 μmol/g ABTS; 45.4 μmol/g DPPH	Payum et al. 2015

66	*Spondias pinnata* (L. f.) Kurz	Anacardiaceae	E, SE Asia, Thailand	leaves, pulp, flower clusters	**antioxidants:** phenolics 210 mg GAE/100 mg of extract; flavonoids 28.0 mg CE/100 mg of extract; flavanol 9.97 mg RE/100 mg of extract; 7.93 mg TE/100 mg of ectract FRAP; IC_{50} 0.59 mg/mL of extract DPPH; TEAC value of extract = 0.83 **minerals:** Ca 174.16 mg/100 g dw; K 66.1 mg/100 g dw; Mg 79.61 mg/100 g dw; Na 38.91 mg/100 g dw; P 108.40 mg/100 g dw; Fe 4.25 mg/100 g dw; Cu 3.45 mg/100 g dw; Mn 4.16 mg/100 g dw; Zn 12.65 mg/100 g dw; Pb 0.207 mg/100 g dw; Sn 1.1 mg/100 g dw; As < 0.01 mg/100 g dw; Cd < 0.01 mg/100 g dw; Hg < 0.001 mg/100 g dw; Se 0.027 mg/100 g dw; Ni 0.082 mg/100 g dw **vitamins:** thiamine 0.46 mg/100 g dw; riboflavin 0.24 mg/100 g dw; niacin 4.24 mg/100 g dw; vitamin C 200.2 mg/100 g dw	Satpathy et al. 2011
					antioxidants: carotenoids 66 μg/100 g; phytosterols 16.51 mg/100 g; phenolics 3,178 mg GAE/100 g; 365 μmol TE/g DPPH; 424 μmol TE/g FRAP; 241 μmol TE/g ORAC **minerals:** Ca 189 mg/100 g; P 28 mg/100 g; Na 13 mg/100 g; K 163 mg/100 g; Mg 45 mg/100 g; Fe 0.22 mg/100 g; Cu 0.03 mg/100 g; Zn 0.12 mg/100 g **vitamins:** vitamin C 37 mg/100 g; vitamin E 1.10 mg/100 g	Judprasong et al. 2013

					antioxidants: ripe fruit: total antioxidant activity IC_{50} 124.25 µg/ml (methanol extract); IC_{50} 92.5 µg/ml reducing power; IC_{50} 97.5 µg/ml DPPH scavenging; IC_{50} 144.0 µg/ml nitric oxide scavenging; IC_{50} 72.25 µg/ml hydrogen peroxide scavenging; phenolics 243.13 mg GAE/100 g dw; flavonoids 183.87 mg QE/100 g dw; tannin 95.60 mg TAE/100 g dw	Mani & Thomas 2020
67	*Spondias lakonensis* Pierre	Anacardiaceae	SE Asia, Thailand	pulp	no data	-
68	*Syzygium aqueum* (Burm.f.) Alston	Myrtaceae	SE Asia	pulp	**antioxidants:** polyphenols 285.80 mg GAE/100 g fw; anthocyanin 75.93 mg C3G/100 g fw; carotenoids 71.17 µg/g fw; tannin 18.55 mg TAE/100 g fw; 97.51 mg AEAC/100 g; antioxidant activity value = 92.40 % (acetone extract); IC_{50} 227.77 µg/mL (aqueous extract)	Singh et al. 2011
					antioxidants: phenolics 30.7 mg GAE/100 g; flavonoids 62.07 µg/g; antioxidant activity 144.5 mg AEAC/100 g; β-carotene 37.28 µg/g **minerals:** Ca 0.64 mg **vitamins:** vitamin C 13.8 mg/100 g	Nallakurumban et al. 2015
					antioxidants: IC_{50} 25.76 µg/mL DPPH; IC_{50} 2,077.18 µg/mL ABTS; IC_{50} 1,512.20 µg/mL hydroxyl radical scavenging; IC_{50} 7,516 µg/mL hydrogen peroxide radical scavenging; IC_{50} 1,304.99 µg/mL nitric oxide radical scavenging; IC_{50} 1,324.31 µg/mL superoxide radical scavenging	Kumar Priyanka & Rajalakshmi 2020

69	*Syzygium malaccense* (L.) Merr. & L.M.Perry	Myrtaceae	SE Asia, Thailand	pulps, flowers, leaves, shoots	**antioxidants:** phenolics 29.55 mg GAE/100 g fw; flavonoids 3.99 mg QE/100 g fw; DPPH scavenging activity 16.75 % inhibition at 1 mg/mL	Anantachoke et al. 2016
					antioxidants: phenolics 8.03 mg GAE/g dw; 25.92 μmol TEAC/g dw DPPH; 0.09 mmol ferreous sulfate/g dw FRAP **vitamins:** vitamin C 175.06 mg/100 g	Nunes et al. 2016
					antioxidants: phenolics 460 mg GAE/100 g; flavonoids 294 mg QE/100 g; anthocyanin 300.54 mg/100 g; carotenoids 0.01–3.93 mg/100 g; 2.59 mmol TE/100 g DPPH; 9 mmol Fe_2SO_4/100 g FRAP value; 137.44 mmol TE/100 g ORAC value **minerals:** P 14.70 mg/100 g; Ca 0.36 mg/100 g; Fe 0.5 mg/100 g **vitamins:** vitamin C 171.14–292.59 mg AEAC/100 g; thiamine 0.03 mg/100 g; riboflavin 0.03 mg/100 g; niacin 0.003/100 g	de Paulo Farias et al. 2020
70	*Tiliacora triandra* Diels	Menispermaceae	SE Asia, Thailand	leaves	**antioxidants:** EC_{50} 14.51 µg/ml DPPH scavenging activity	Phadungkit et al. 2012
					antioxidants: phenolics 97.899 mg GAE/g (water extract); IC_{50} 0.197 mg/g DPPH (water extract); IC_{50} 0.077 mg/g ABTS (water extract); 0.054 mmol Fe (II)/g FRAP	Singthong et al. 2014
71	*Uvaria grandiflora* Roxb. Ex Hornem.	Annonaceae	SE Asia, Thailand	pulp	no data	-

72	*Wolffia globosa* (Roxb.) Hartog & Plas	Araceae	tropical Asia	leaves	**antioxidants:** freeze-dried weight: β-carotene 19.1 mg/100g; lutein 58.1 mg/100 g; zeaxanthin 1.89 mg/100 g **minerals:** freeze-dried weight: Fe 0.037 mg/100 g; Mn 30.2 mg/100 g; Cu 0.443 mg/100 g; Zn 8.42 mg/100 g; I 0.05 mg/100 g; Se<0.003 mg/100 g; Ca 2,520 mg/100 g; K 5,460 mg/100g; Mg 3,170 mg/100 g; Na 310 mg/100 g; P 1,710 mg/100 g **vitamins:** freeze-dried weight: α-tocopherol 7.9 mg/100 g	Appenroth et al. 2018
					vitamins: cobalamin 2.8 μg/100 g dw	Sela et al. 2020
73	*Ziziphus jujuba* Mill.	Rhamnaceae	SE Asia, Thailand	pulp, seeds, leaves	**antioxidants:** carotene 0.021 mg/100 g fw **minerals:** Ca 25.6 mg/100 g fw; P 26.8 mg/100 g fw; Fe 0.76–1.8 mg/100 g fw **vitamins:** thiamine 0.02-0.024 mg/100 g fw; riboflavin 0.02-0.038 mg/100 g fw; niacin 0.7-0.873 mg/100 g fw; vitamin C 65.8-76.0 mg/100 g fw	Pareek 2013
					antioxidants: phenolics 45.29 mg GAE/100 g fw; flavonoids 1.36 mg QE/100 g fw; DPPH scavenging activity 4.45 % inhibition at 1 mg/mL	Anantachoke et al. 2016
					minerals: PSI cultivar: K 1,730 mg/100 g dw; Ca 720 mg/100 g dw; Mg 770 mg/100 g dw; Na 430 mg/100 g dw; Fe 1.71 mg/100 g dw; Zn 0.40 mg/100 g dw (cultivar MSI 0.48 mg/100 g dw); Cu 0.05 mg/100 g dw (cultivar MSI 0.12 mg/100 g dw); Mn 0.29 mg/100 g dw	Hernández et al. 2016

		antioxidants: polyphenols 8.76–21.61 mg GAE/g; flavonoids 1.49–11.57 μg QE/g; carotenoid 1.53–14.31 μg/g; 11.18–16.82 mg TEAC/g DPPH; 209.64–481.55 mg TEAC/g dw molybdenum reducing antioxidant power	Ivanišová et al. 2017
		antioxidants: carotene 0.01 mg/100 g **minerals:** Ca 14 mg/100 g; P 23 mg/100 g; Fe 0.5 mg/100 g **vitamins:** vitamin C 200–800 mg/100 g; thiamine 0.06 mg/100 g; riboflavin 0.04 mg/100 g; niacin 0.6 mg/100 g	Liu et al. 2020

Footnotes: [1] = verified in The Plant list Database; [2] = verified in Useful Tropical Plants Database; [3] = based on information obtained from scientific literature cited in the references; AAE = ascorbic acid equivalent; ABTS = 2, 2′-Azinobis (3-ethylbenothiazoline-6-sulfonic acid) diammonium salt; AEAC = ascorbic acid equivalent antioxidant capacity; BHAE = t-butylated hydroxyanisole equivalent; C3G = cyanidin-3-glucoside equivalent; CCE = cyanidin chloride equivalent; CE = catechin equivalent; CUPRAC = modified cupric reducing antioxidant capacity; DPPH = 2,2-diphenyl-1-picryl-hydrazyl-hydrate; dw = dry weight basis; E = east; EC_{50} = half maximal effective concentration; EDTAE = ethylenediaminetetraacetic acid equivalent; FRAP = ferric reducing antioxidant power; fw = fresh weight basis; GAE = gallic acid equivalent; IC_{50} = half maximal inhibitory concentration; IU = International Unit; ORAC = oxygen radical absorbance capacity; QE = quercetin equivalent; RE = rutin equivalent; S^t = south; SE = southeast; TAE = tannic acid equivalent; TE = trolox equivalent; TEAC = trolox equivalent antioxidant activity

5. Conclusions

Fruit and vegetable species play a huge role in human nutrition. They are irreplaceable sources of essential substances needed for human health (FAO 1995; Valíček 2002; Hall et al. 2009; Pem & Jeewon 2015). Contained substances include antioxidants, minerals, and vitamins, on which this thesis was focused, and other biologically active substances such as primary metabolites (carbohydrates, lipids, proteins) and secondary metabolites (alkaloids, phenolics, terpenoids), and water (Dauthy 1995; Hounsome et al. 2008; Kabera et al. 2014). Insufficient income of fruits and vegetables together with an unhealthy lifestyle is associated with the development of non-communicable diseases such as cancer, cardiovascular diseases, diabetes, obesity, and many others. In addition, non-communicable diseases are the most common cause of death in the world. Another problem in human nutrition are diseases associated with deficiencies of essential micronutrients which persist in less developed parts of the world (FAO & WHO 2004).

Thailand, which is a part of the Indo-Burma Biodiversity Hotspot, is one of the most biodiverse countries in the world and countless fruits and vegetables are grown there, including underutilized species. Thai cuisine is considered healthy and delicious. Rice is used as a staple food and consumed with meat or fish and various kinds of vegetables. Each of the 4 regions of Thailand has its own customs and traditions and uses different ingredients in traditional local cuisine. Homegardens are often the source of such ingredients and function as multi-use, multi-story, small-scale land-use systems and provide various plants, be they food crops, medicinal plants, or ornamental plants. Homegardens are also important sites of wild species domestication (Srithi et al. 2012; Thailand Foundation & Ministry of Foreign Affairs of Thailand 2014).

Underutilized species have the potential to fight against malnutrition due to their significant nutritional values. But high content of essential components is not the only beneficial property of underutilized species. They are considered more resistant to biotic stresses, can grow in unfavourable climatic conditions, and have the ability to strengthen the food security and economy of the country (Padulosi et al. 2013; Hunter et al. 2019).

It has been found that some of them have a significant content of micronutrients while remaining neglected (Padulosi et al. 2013; Sirichamorn 2014).

In this thesis, 73 underutilized fruit and vegetable species of 32 families originating or naturalized in Thailand were identified. For 8 of them, data on the content of antioxidants, minerals, and vitamins were not available. Also, data on all three monitored parameters together were found in only 34 species. For other species, at least 1 monitored parameter was missing.

In the terms of antioxidants, it is very difficult to determine the most interesting species because of the variability of the measurement methods used and the different units in which the results are expressed. The most common methods mentioned were determination of IC_{50} (half maximal inhibitory concentration) and expression of antioxidant content using different equivalents (trolox equivalent, rutin equivalent, and others). If focused on IC_{50}, *Durio kutejensis* showed the best antioxidant activity with IC_{50} 1.0 µg/mL ABTS (using ethyl acetate solvent) (Arung et al. 2015). *D. kutejensis* has about 20 cm long ellipsoid fruit with thick-textured, yellowish-orange flesh which is eaten raw but is less sweet than commonly knew durian (*D. zibethinus*). Another interesting species with high antioxidant activity is *Cosmos caudatus* which provides various antioxidants such as carotenoids, kaempferol, quercetin, and many others. *C. caudatus* is an herb originating in Latin America but was naturalized as a weed pantropically. Leaves and tops are consumed raw or cooked. It can be added to salads and stews (Rafat et al. 2010; Andarwulan et al. 2012; Bunawan et al. 2014; Useful Tropical Plants Database 2014; Cheng et al. 2015).

Determination of the species with the highest mineral content was difficult due to different measurement methods, with some research using a dry matter of the plant, while other research using fresh matter. *Neptunia oleracea* showed significant content of minerals such as calcium, copper, magnesium, manganese, phosphorus, potassium, and zinc. Crisp and juicy leaves, stems, and young seedpods of *N. oleracea* are consumed raw or cooked and can be added to salads. Although the origin of *N. oleracea* is uncertain, it is widely distributed in Southeast Asia. Also, *Dracontomelon dao* and *Gnetum gnemon* have shown to be species with valuable mineral contents. *D. dao*, of which the fruits are eaten raw, or cooked with soy sauce and served with rice showed interesting contents of calcium, chlorine, cobalt, chromium, iron, magnesium, manganese, potassium, sodium, and zinc. *G. gnemon* showed high contents of calcium, copper, iron, magnesium, manganese, phosphorus, potassium, and zinc. *G. gnemon* is a multipurpose tree of which leaves are consumed raw or cooked, seeds are consumed cooked, inflorescences and fruits are added to soups, peel of the fruit is dried and used in soups, and the stem sap is drinkable (Majid et al. 1995; Bhat & Binti Yahya 2014; Useful Tropical Plants Database 2014; Kongkachuichai et al. 2015; Ainul Asyira et al. 2016).

The evaluation of vitamin-rich species was similar to the evaluation of mineral-rich species, again using methods of dry matter and fresh matter that make the determination difficult. The most interesting contents of vitamins (A, B_1, B_2, B_3, C, E) were observed in *Aegle marmelos*, *Mangifera odorata*, and *Sesbania grandiflora*. Pleasant-flavoured yellow fruits of *A. marmelos* are consumed raw or processed into jams, sweets, and beverages. *M. odorata* is a crop with local economic significance in the areas where the mango (*M. indica*) cannot be cultivated due to high humidity. The origin remains unknown but according to scientific studies, *M. odorata* is a hybrid of *M. foetida* and *M. indica*, so Southeast Asia appears to be the place of origin. *S. grandiflora* is a loosely branching tree with edible flowers, gum, leaves, seedpods, seeds, and shoots. Very interesting is also *Wolffia globose*, also known as a Khai Nam, which was the only cobalamin (vitamin B_{12}) containing species. *W. globose* is an aquatic plant of which leaves are consumed cooked because of their excellent flavour like sweet cabbage (Duke 1983; Reddy & Urooj 2013; Useful Tropical Plants Database 2014; Pandey et al. 2015; Mirfat et al. 2016; Barbosa Gámez et al. 2017; Sela et al. 2020).

The most promising crops with the widest spectra of antioxidants, minerals, and vitamins seem to be already above-mentioned *A. marmelos* (Appendix I.), and *S. grandiflora* (Appendix II.), but also *Spondias pinnata* (Appendix III.), and *Ziziphus jujuba* (Appendix IV.). *S. pinnata* is a deciduous tree of which the leaves are added to stews for their sour flavour. Fruits and flowers are consumed raw or cooked. *Z. jujuba* is an evergreen thorny tree in which the fruits are consumed raw or preserved, sweet raw seeds are consumed as a snack, and young leaves can be cooked as a vegetable (Useful Tropical Plants Database 2014). It would be appropriate to promote these species more to the local people as they could enrich their diet and increase their financial incomes and standard of living. Also, such species could be used in industry and for the production of various food products such as beverages, desserts, or even food supplements.

For 8 species no data were available on antioxidant activity or mineral and vitamin content. It would be therefore appropriate to focus on their research. Such research could provide very interesting and useful information and could reveal the undiscovered nutritional potential of some underutilized species originating in Thailand. Indeed, some of the underutilized fruits and vegetables may have enormous potential, and exploring them could revolutionize the fight against malnutrition, diseases of affluence, and various environmental problems.

6. References

Abu Bakar MF, Abdul Karim F, Perisamy E. 2015. Comparison of phytochemicals and antioxidant properties of different fruit parts of selected Artocarpus species from Sabah, Malaysia. Sains Malaysiana **44**: 355–363.

Afolabi OB, Oloyede OI, Ojo AA, Onansanya AA, Agunbiade SO, Ajiboye BO, Johnson J, Peters OA. 2018. In vitro antioxidant potential and inhibitory effect of hydro-ethanolic extract from African black velvet tamarind (Dialium indium) pulp on type 2 diabetes linked enzymes. Potravinarstvo **12**: 413–421.

Agarwal P, Gaur PK, Tyagi N, Puri D, Kumar N, Kumar SS. 2019. An Overview of Phytochemical, Therapeutic, Pharmacological and Traditional Importance of Syzygium cumini. Asian Journal of Pharmacognosy **3**: 5–17.

Aguilar TAF, Navarro BCH, Pérez JAM. 2016. Endogenous Antioxidants: A Review of their Role in Oxidative Stress. Pages 3–19 in Morales-Gonzalez JA, Morales-Gonzalez A, Madrigal-Santillán EO, editors. A Master Regulator of Oxidative Stress - The Transcription Factor Nrf2. IntechOpen, London, United Kingdom.

Ainul Asyira S, Noorasmah S, Sarbini SR, Muta Harah Z. 2016. Mineral content of fi ve indigenous leafy vegetables from bintulu market, Sarawak Malaysia. Journal of Medicinal Herbs and Ethnomedicine **2**: 26–35.

Akram M, Munir N, Daniyal M, Egbuna C, Găman M-A, Onyekere PF, Olatunde A. 2020. Vitamins and Minerals: Types, Sources and their Functions. Pages 149–172 in Egbuna C, Dable Tupas G, editors. Functional Foods and Nutraceuticals. Springer, Cham.

Akter MS, Oh S, Eun J-B, Ahmed M. 2011. Nutritional compositions and health promoting phytochemicals of camu-camu (myrciaria dubia) fruit: A review. Food Research International **44**: 1728–1732.

Alakolanga AGAW, Kumar NS, Jayasinghe L, Fujimoto Y. 2015. Antioxidant property and α-glucosidase, α-amylase and lipase inhibiting activities of Flacourtia inermis fruits: characterization of malic acid as an inhibitor of the enzymes. Journal of Food Science and Technology **52**: 8383–8388.

Al-Gubory KH, Laher I. 2017. Nutritional Antioxidant Therapies: Treatments and Perspectives. Springer International Publishing AG, Switzerland.

Alia, Mohanty P, Matysik J. 2001. Effect of proline on the production of singlet oxygen. Amino Acids **21**:195–200.

Allen LH. 2012. Vitamin B-12. Advances in Nutrition **3**: 54–55.

Anantachoke N, Lomarat P, Praserttirachai W, Khammanit R, Mangmool S. 2016. Thai Fruits Exhibit Antioxidant Activity and Induction of Antioxidant Enzymes in HEK-293 Cells. Evidence-Based Complementary and Alternative Medicine **2016**: (6083136) doi: 10.1155/2016/6083136.

Andarwulan N, Batari R, Sandrasari DA, Bolling B, Wijaya H. 2010. Flavonoid content and antioxidant activity of vegetables from Indonesia. Food Chemistry **121**: 1231–1235.

Andarwulan N, Kurniasih D, Apriady RA, Rahmat H, Roto AV, Bolling BW. 2012. Polyphenols, carotenoids, and ascorbic acid in underutilized medicinal vegetables. Journal of Functional Foods **4**: 339–347.

Anitha T, Mary Josephine R. 2014. MINERAL PROFILE OF EDIBLE GREEN LEAFY VEGETABLE - SESBANIA GRANDIFLORA (L.) PERS. International Journal of Current Research **6**: 10074–10076.

Appenroth K-J et al. 2018. Nutritional Value of the Duckweed Species of the Genus Wolffia (Lemnaceae) as Human Food. Frontiers in Chemistry **6**: (483) doi: 10.3389/fchem.2018.00483.

Arung ET, Suwinarti W, Hendra M, Supomo S, Kusuma IW, Puteri DCN, Eroglu HA, Kim Y, Shimizu K, Ishikawa H. 2015. Determination of Antioxidant and Anti-Melanogenesis Activities of Indonesian Lai, Durio kutejensis [Bombacaceae (Hassk) Becc] Fruit Extract. Tropical Journal of Pharmaceutical Research **14**: 41–46.

Asia Discovery. 2011. Thailand Travel. Royal Exclusive Travel Co., Thailand. Available from https://www.asia-discovery.com/thai_foods.htm (accessed March 2021).

Atta EM, Mohamed NH, Abdelgawad AAM. 2017. ANTIOXIDANTS: AN OVERVIEW ON THE NATURAL AND SYNTHETIC TYPES. European Chemical Bulletin **6**: 365–375.

Attaluri P, Castillo A, Edriss H, Nugent K. 2018. Thiamine Deficiency: An Important Consideration in Critically Ill Patients. The Americal Journal of the Medical Sciences **356**: 382–390.

Awuchi CG, Igwe VS, Amagwula IO, Echeta CK. 2020. Health Benefits of Micronutrients (Vitamins and Minerals) and their Associated Deficiency Diseases: A Systematic Review. International Journal of Food Sciences **3**: 1–32.

Bahorun T, Neergheen VS, Aruoma OI. 2011. Phytochemical constituents of iCassia fistula/i. African Journal of Food, Agriculture, Nutrition and Development **4**: 1530–1540.

Balaji K, Nedumaran SA, Devi T, Sikawar MS, Fuloria S. 2015. Phytochemical analysis and in vitroantioxidant activity of Parkia speciosa. International Journal of Green Pharmacy **9**: S50–S54.

Barbosa Gámez I, Caballero Montoya KP, Ledesma N, Sáyago Ayerdi SG, García Magaña M de L, Bishop von Wettberg EJ, Montalvo-González E. 2017. Changes in the nutritional quality of five Mangifera species harvested at two maturity stages. Journal of the Science of Food and Agriculture **97**: 4987–4994.

Barthakur NN, Arnold NP. 1991[a]. A chemical analysis of the Indian star apple (Chrysophyllum roxburghii) fruit. Journal of Food Composition and Analysis **4**: 354–359.

Barthakur NN, Arnold NP. 1991[b]. Chemical analysis of the emblic (Phyllanthus emblica L.) and its potential as a food source. Scientia Horticulturae **47**: 99–105.

Bazzano LA, He J, Ogden LG, Loria C, Vupputuri S, Myers L, Whelton PK. 2001. Dietary Potassum Intake and Risk of Stroke in US Men and Women. Stroke **32**: 1473–1480.

Beckett EL, Yates Z, Veysey M, Duesing K, Lucock M. 2014. The role of vitamins and minerals in modulating the expression of microRNA. Nutrition Research Reviews **27**: 94–106.

Bender DA. 2009. Nutritional Biochemistry of the Vitamins, Second Edition. Cambridge University Press, United Kingdom.

Bendich A, Machlin LJ. 1988. Safety oral intake of vitamin E. The American Journal of Clinical Nutrition **48**: 612–619.

Bhat R, Binti Yahya N. 2014. Evaluating belinjau (Gnetum gnemon L.) seed flour quality as a base for development of novel food products and food formulations. Food Chemistry **156**: 42–49.

Bhatta R, Saravanan M, Baruah L, Sampath KT. 2012. Nutrient content, in vitro ruminal fermentation characteristics and methane reduction potential of tropical tannin-containing leaves. Journal of the Science of Food and Agriculture **92**: 2929–2935.

Bhogaonkar PY, Rajgure YM, Kadu SROV. 2016. NUTRITIONAL AND PHYTOCHEMICAL PROFILE OF BOMBAX CEIBA L. FLOWERS – A WILD EDIBLE. International Journal of Recent Scientific Research **7**: 13823–13825.

Böhm V. 2018. Vitamin E. Antioxidants **7**: 1–2.

Boruah MP, Handique JG. 2014. Antioxidant Behavior of some North East Indian Ethno Medicinal Vegetables and their RP-HPLC Analysis. INTERNATIONAL JOURNAL OF ADVANCES IN PHARMACY, BIOLOGY AND CHEMISTRY **3**: 426–433.

Bouayed J, Bohn T. 2010. Exogenous Antioxidants—Double-Edged Swords in Cellular Redox State: Health Beneficial Effects at Physiologic Doses versus Deleterious Effects at High Doses. Oxidative Medicine and Cellular Longevity **3**: 228–237.

Brigelius-Flohé R, Traber MG. 1999. Vitamin E: function and metabolism. The FASEB Journal: **13**: 1145–1155.

Britannica. 2011. Chlorine deficiency. Encyclopedia Britannica Inc. Available from https://www.britannica.com/science/chlorine-deficiency (accessed January 2021).

Broderick JB. 2001. Encyclopedia of Life Sciences. John Wiley, Chichester, UK.

Buang Y. 2011. The Effects of Dietary Food Fortified with Vitamin B4 on Lipid Profiles in Serum and Liver Tissue. Makara Journal of Health Research **14**: 1–4.

Bunawan H, Baharum AN, Bunawan SN, Amin NM, Noor NM. 2014. Cosmos Caudatus Kunth: A Traditional Medicinal Herb. Global Journal of Pharmacology **8**: 420–426.

Butterworth CE, Tamura T. 1989. Folic acid safety and toxicity: a brief review. The American Journal of Clinical Nutrition **50**: 353–358.

Cadet J, Loft S, Olinski R, Evans MD, Bialkowski K, Wagner JR, Dedon PC, Møller P, Greenberg MM, Cooke MS. 2012. Biologically relevant oxidants and terminology, classification and nomenclature of oxidatively generated damage to nucleobases and 2-deoxyribose in nucleic acids. Free Radical Research **46**: 367–381.

Canadian Academy of Sports Nutrition. 2020. Vitamin B4 (Adenine). Canadian Academy of Sports Nutrition, Canada. Available from caasn.com/vitamin-b4-adenine.html/ (accessed February 2021).

Cerklewski FL. 1997. Fluoride bioavailability – Nutritional and clinical aspects. Nutrition research **17**: 907–929.

Česká průmyslová zdravotní pojišťovna. 2021. Civilizační onemocnění. Česká průmyslová zdravotní pojišťovna. Available from https://www.cpzp.cz/clanek/5502-0-Civilizacni-onemocneni.html (accessed February 2021).

Chan EWC, Lim YY, Wong LF, Lianto FS, Wong SK, Lim KK, Joe CE, Lim TY. 2008. Antioxidant and tyrosinase inhibition properties of leavesand rhizomes of ginger species. Food Chemistry **109**: 477–483.

Chan KN, Nyein CN, Thida M, Ei SL, Nwe MT, Lwin WW, Mya KM. 2019. In vitro Free Radical Scavenging Activity of Some Myanmar Traditional Plant Extracts. Hamdard Medicus **61**: 41–51.

Chan-Blanco Y, Vaillant F, Mercedes Perez A, Reynes M, Brillouet J-M, Brat P. 2006. The noni fruit (Morinda citrifolia L.): A review of agricultural research, nutritional and therapeutic properties. Journal of Food Composition and Analysis **19**: 645–654.

Chandrika UG, Jansz ER, Warnasuriya ND. 2005. IDENTIFICATION AND HPLC QUANTIFICATION OF CAROTENOIDS OF THE FRUIT PULP OF

CHRYSOPHYLLUM ROXBURGHII. Journal of the National Science Foundation of Sri Lanka **33**: 93–98.

Chanwitheesuk A, Teerawutgulrag A, Rakariyatham N. 2005. Screening of antioxidant activity and antioxidant compounds of some edible plants of Thailand. Food Chemistry **92**: 491–497.

Chao P-Y, Lin S-Y, Lin K-H, Liu Y-F, Hsu J-I, Yang C-M, Lai J-Y. 2014. Antioxidant Activity in Extracts of 27 Indigenous Taiwanese Vegetables. Nutrients **6**: 2115–2130.

Charoenchai L, Settharaksa S, Madaka F, Sueree L. 2015. EVALUATION OF THE ANTIOXIDANT ACTIVITIES, TOTAL PHENOLIC AND FLAVONOID CONTENTS OF MELIENTHA SUAVIS PIERRE. Bulletin of Health, Science and Technology **12**: 29–37.

Charoensiddhi S, Anprung P. 2008. Bioactive compounds and volatile compounds of Thai bael fruit (Aegle marmelos (L.) Correa) as a valuable source forfunctional food ingredients. International Food Research Journal **15**: 287–295.

Chauhan A, Tanwar B, Arneja I. 2015. INFLUENCE OF PROCESSING ON PHYSIOCHEMICAL, NUTRITIONAL AND PHYTOCHEMICAL COMPOSITION OF CARISSA SPINARUM (KARONDA) FRUIT. Asian Journal of Pharmaceutical and Clinical Researcch **8**: 254–259.

Chenault HK, Simon ES, Whitesides GM. 1988. Cofactor Regeneration for Enzyme-Catalysed Synthesis. Biotechnology and Genetic Engineering Reviews **6**: 221–270.

Cheng S-H, Barakatun-Nisak MY, Anthony J, Ismail A. 2015. Potential medicinal benefits of Cosmos caudatus (Ulam Raja): A scoping review. Journal of Research in Medical Sciences **20**: 1000–1006.

Chhikara N, Devi HR, Jaglan S, Sharma P, Gupta P, Panghal A. 2018. Bioactive compounds, food applications and health benefits of Parkia speciosa (stinky beans): a review. Agriculture & Food Security **7**: 1–9.

Cho S-H. 2010. Vitamin E: α-Tocopherol and the Other Forms of Vitamin E. The Korean Journal of Nutrition **43**: 304–314.

Colovic MB, Vasic VM, Djuric DM, Krstic DZ. 2018. Sulpur-containing Amino Acids: Protective Role Against Free Radicals and Heavy Metals. Current Medicinal Chemistry **25**: 324–335.

Combet E, Buckton C. 2019. Micronutrient deficiencies, vitamin pills and nutritional supplements. Medicine **47**: 145–151.

Combs GF. 2012. The vitamins: [fundamental aspects in nutrition and health], 4th ed. Elsevier, Amsterdam.

Convention on Biological Diversity. 2021. Thailand – Main Details. Convention on Biological Diversity, Montreal, Canada. Available from https://www.cbd.int/countries/profile/?country=th (accessed March 2021).

Costa AGV, Garcia-Diaz DF, Jimenez P, Silva PI. 2013. Bioactive compounds and health benefits of exotic tropical red–black berries. Journal of Functional Foods **5**: 539–549.

Cummings JH, Stephen AM. 2007. Carbohydrate terminology and classification. European Journal of Clinical Nutrition **61**: S5–S18.

Dauthy ME. 1995. Fruit and vegetable processing. FAO, Rome.

de Paulo Farias D, Neri-Numa IA, de Araújo FF, Pastore GM. 2020. A critical review of some fruit trees from the Myrtaceae family as promising sources for food applications with functional claims. Food Chemistry **306**: (125630) doi: 10.1016/j.foodchem.2019.125630.

De Romaña DL, Olivares M, Uauy R, Araya M. 2011. Risks and benefits of copper in light of new insights of copper homeostasis. Journal of Trace Elements in Medicine and Biology **25**: 3–13.

DeFedericis H-C, Patrzyc HB, Rajecki MJ, Budzinski EE, Iijima H, Dawidzik JB, Evans MS, Greene KF, Box HC. 2006. Singlet Oxygen-Induced DNA Damage. Radiation Research **165**: 445–451.

Devaki SJ, Raveendran RL. 2017. Vitamin C: Sources, Functions, Sensing and Analysis. Pages 3–20 in Hamza A, editor. Vitamin C. IntechOpen, London, United Kingdom.

DiNicolantonio JJ, Bhutani J, O'Keefe JH. 2015. The health benefits of vitamin K. Open Hearth **2**: (e000300) doi:10.1136/openhrt-2015-000300.

Dixit AK, Kumar V, Maloni N, Sarkar M, Shrivastava B, Nair PG, Rotwar DS, Mundada P. 2019. Comparative Assessment of Phytochemicals, Antioxidant, and Antimicrobial Potential of Stem Bark and Small Branches of Buchanania cochinchinensis (Lour.) MR Almeida for Substitution in Ayurvedic Drugs. Journal of Drug Research in Ayurvedic Sciences **4**: 72–83.

Djuita NR, Hartana A, Chikmawati T, Dorly D. 2017. Characteristics and Ideotype Formulation of Pulasan (Nephelium ramboutan-ake) Fruit Landrace from West Java, Indonesia. Makara Journal of Science **21**: 69–76.

Do TVT, Suhartini W, Mutabazi F, Mutukumira AN. 2020. Gynura bicolor DC. (Okinawa spinach): A comprehensive review on nutritional constituents, phytochemical compounds, utilization, health benefits, and toxicological evaluation. Food Research International **134**: 1–20.

Duke JA. 1983. Handbook of Energy Crops. Purdue University, Center for New Crops & Plants Products. Available from https://hort.purdue.edu/newcrop/duke_energy/dukeindex.html (accessed March 2021).

Dunkhunthod B, Talabnin C, Murphy M, Thumanu K, Sittisart P, Eumkeb G, Carocho M. 2021. Gymnema inodorum (Lour.) Decne. Extract Alleviates Oxidative Stress and Inflammatory Mediators Produced by RAW264.7 Macrophages. Oxidative Medicine and Cellular Longevity **2021**: (8658314) doi: 10.1155/2021/8658314.

El-Youssef M. 2008. Wilson's Disease. Pages 597–607 in Heggenhougen HK, editor. International Encyclopedia of Public Health. Elsevier Inc, United Kingdom.

European Food Safety Authority. 2006. TOLERABLE UPPER INTAKE LEVELS FOR VITAMINS AND MINERALS. Dictus Publishing, Italy. Available from https://www.efsa.europa.eu/sites/default/files/efsa_rep/blobserver_assets/ndatolerableuil.pdf (accessed February 2021).

European Food Safety Authority. 2015. Scientific Opinion on Dietary Reference Values for vitamin E as α-tocopherol. EFSA Journal **13**: 1–3.

European Fresh Produce Association. 2015. World Production of Fruits and Vegetables. European Fresh Produce Association, Brussels, Belgium. Available from https://www.freshfel.org/docs/FAQ/Fact_Sheet_-_world_production_2009_-_2013.pdf (accessed February 2021).

Ezzati M, Vander Hoorn S, Lawes CMM, Leach R, James WPT, Lopez AD, Rodgers A, Murray CJL. 2005. Rethinking the "Diseases of Affluence" Paradigm: Global Patterns of Nutritional Risks in Relation to Economic Development. PLoS Medicine **2**: 0404–0412.

Fadiyah I, Lestari I, Mahardika RG. 2020. Antioxidant Capacity of Rukam Fruit Extract (Flacourtia rukam) Using Microwave Assisted Extraction (Mae) Method. Indonesian Journal of Chemical Research **7**: 107–113.

Fain O. 2004. Carences en vitamine C. La revue de médecine Interne **25**: 872–880.

Fairulnizal Md Noh M, Gunasegavan RDN, Mustar S. 2019. Vitamin A in Health and Disease. Pages 11–32 in Zepka LQ, de Rosso VV, Jacob-Lopes E, editors. Vitamin A. IntechOpech, London, United Kingdom.

Fairweather-Tait SJ, Bao Y, Broadley MR, Collings R, Ford D, Hesketh JE, Hurst R. 2011. Selenium in Human Health and Disease. Antioxidants & Redox Signaling **14**: 1337–1383.

FAOSTAT. 2020. Thailand. Food and Agriculture Organization of the United Nations, Rome. Available from http://www.fao.org/countryprofiles/index/en/?iso3=THA (accessed March 2020).

Finley JW, Davis CD. 1999. Manganese deficiency and toxicity: Are high or low dietary amounts of manganese cause for concern? BioFactors **10**: 15–24.

Food and Agriculture Organization of the United Nations, World Health Organization. 2004. Fruit and Vegetables for Health. FAO & WHO, Italy. Available from https://apps.who.int/iris/bitstream/handle/10665/43143/9241592818_eng.pdf;jsessionid=B3586C85DAA4E0FD69CD64FB22500BA4?sequence=1 (accessed February 2021).

Food and Agriculture Organization of the United Nations. 1995. Staple foods: What do people eat? Pages 21–24 in Loftas T, editor. Dimensions of NEED – An Atlas of Food and Agriculture. Food and Agriculture organization of the United Nations, Rome.

Food and Agriculture Organization of the United Nations. 2001. Under-Utilized Tropical Fruits of Thailand. Food and Agriculture Organization of the United Nations – Regional Office for Asia and the Pacific, Bangkok, Thailand.

Food and Agriculture Organization of the United Nations. 2003. Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas. Food and Agriculture Organization of the United Nations, Rome.

Food and Agriculture Organization of the United Nations. 2011. AQUASTAT Country Profile – Thailand. Food and Agriculture Organization of the United Nations, Rome.

Food and Agriculture Organization of the United Nations. 2020[a]. Statistical Yearbook 2020. Food and Agriculture Organization of the United Nations, Rome.

Food and Agriculture Organization of the United Nations. 2020[b]. Fruit and vegetables – your dietary essentials. FAO, Rome.

Food and Agriculture Organization of the United Nations. 2021. Family Farming Knowledge Platform. Food and Agriculture Organization of the United Nations, Rome. Available from http://www.fao.org/family-farming/countries/tha/en/ (assecced March 2021).

Food Browser. 2020. Food Browser Version 1.0. Food Browser, Canada. Available from https://foodb.ca/ (assecced February 2021).

Fraga C. 2002. Iron toxicity and antioxidant nutrients. Toxicology **180**: 23–32.

Gasperi V, Sibilano M, Savini I, Catani M. 2019. Niacin in the Central Nervous System: An Update of Biological Aspects and Clinical Applications. International Journal of Molecular Sciences **20**: (974) doi:10.3390/ijms20040974.

Gharibzahedi SMT, Jafari SM. 2017. The importance of minerals in human nutrition: Bioavailability, food fortification, processing effects and nanoencapsulation. Trends in Food Science & Technology **62**: 119–132.

Ghasemzadeh A, Jaafar HZE, Bukhori MFM, Rahmat MH, Rahmat A. 2018. Assessment and comparison of phytochemical constituents and biological activities of bitter bean (Parkia speciosa Hassk.) collected from different locations in Malaysia. Chemistry Central Journal **12**: 1–9.

Gogoi N, Gogoi A, Neog B, Baruah D, Singh KD. 2017. Evaluation of antioxidant and hepatoprotective activity of fruit rind extract of Garcinia dulcis (Roxburgh) Kurz. Pharmacognosy Research **9**: 266–272.

Gough DR, Cotter TG. 2011. Hydrogen peroxide: a Jekyll and Hyde signalling molecule. Cell Death and Disease **2**: 1–8.

Hall JN, Moore S, Harper SB, Lynch JW. 2009. Global Variability in Fruit and Vegetable Consumption. American Journal of Preventive Medicine **36**: 402–409.

Halliwell B, Aeschbach R, Löliger J, Aruoma OI. 1995. The characterization of antioxidants. Food and Chemical Toxicology **33**: 601–617.

Hamid MA, Wen PK, Mamat H, Ibrahim SS. 2012. Determination of Nutritional Composition and Effect of Various Storage Conditions on the Vitamin C Content in Garcinia Dulcis, in Fresh and Dry Form. International Journal on Advanced Science, Engineering and Information Technology **2**: 313–318.

Hardeland R. 2017. The Underrated Carbonate Radical (CO3•–) – Detoxification and Reduced Formation by Melatonin. Biomed J Sci & Tech Res **1-2017**: 1–4.

Hardinsyah, Windardi IP, Aries M, Damayanthi E. 2019. Total Phenolic Content, Quercetin, and Antioxidant Activity of Gandaria (Bouea Macrophylla Griff.) Leaf Extract at Two Stages of Maturity **14**: 61–68.

Hasan MM, Hossain A, Shamim A, Rahman MM. 2017. Phytochemical and pharmacological evaluation of ethanolic extract of Lepisanthes rubiginosa L. leaves. BMC Complementary and Alternative Medicine **17**: 1–11.

Hasan R, Islam N, Islam R. 2016. Phytochemistry, pharmacological activities and traditional uses of Emblica officinalis: A review. International Current Pharmaceutical Journal, January **5**: 14–21.

Hernández F, Noguera-Artiaga L, Burló F, Wojdyło A, Carbonell-Barrachina ÁA, Legua P. 2016. Physico-chemical, nutritional, and volatile composition and sensory profile of Spanish jujube (Ziziphus jujuba Mill.) fruits. Journal of the Science of Food and Agriculture **96**: 2682–2691.

Hidayah N, Lubis R, Nurhaita. 2020. Comparison of Vitamin, Anthocyanin, and Bioactive Compounds from Gajah and Padi Jengkol (Archidendron jiringa) Peel as Potential Natural Antioxidants. IOP Conference Series: Earth and Environmental Science **465**: 1–5.

Hoe VB, Siong KH. 1999. The nutritional value of indigenous fruits and vegetables in Sarawak. Asia Pacific Journal of Clinical Nutrition **8**: 24–31.

Holick MF, Chen TC. 2008. Vitamin D deficiency: a worldwide problem with health consequences. The American Journal of Clinical Nutrition **87**: 1080S–1086S.

Hossain F, Islam A, Akhtar S, Anwar M. 2017. Nutritional Value and Medicinal Uses of Minor Fruits: Burmese Grape (Baccaurea ramiflora Lour.). International Journal of Nutrition and Food Sciences **6**: 211–214.

Hounsome N, Hounsome B, Tomos D, Edwards-Jones G. 2008. Plant Metabolites and Nutritional Quality of Vegetables. Journal of Food Science **73**: 48–65.

Huda-Faujan N, Noriham A, Norrakiah AS, Babji AS. 2009. Antioxidant activity of plants methanolic extracts containing phenolic compounds **8**: 484–489.

Hunter D et al. 2019. The potential of neglected and underutilized species for improving diets and nutrition. Planta **250**: 709–729.

Hussein RA, El-Anssary A. 2019. Plants Secondary Metabolites: The Key Drivers of the Pharmacological Actions of Medicinal Plants. Pages 11–30 in Builders PF, editor. Herbal Medicine. IntechOpen, United Kingdom.

Ikram EHK, Eng KH, Jalil AMM, Ismail A, Idris S, Azlan A, Nazri HSM, Diton NAM, Mokhtar RAM. 2009. Antioxidant capacity and total phenolic content of Malaysian underutilized fruits. Journal of Food Composition and Analysis **22**: 388–393.

InTeGrate (Interdisciplinary Teaching about Earth for a Sustainable Future). 2018. "Diseases of Affluence": Not Just for the Affluent. InTeGrate. Available from https://serc.carleton.edu/integrate/teaching_materials/food_supply/student_materials/1205 (accessed February 2021).

Irawan D, Wijaya CH, Limin SH, Hashidoko Y, Osaki M, Kulu IP. 2006. Ethnobotanical study and nutrient potency of local traditional vegetables in Central Kalimantan. Tropics **15**: 441–448.

Islary A, Sarmah J, Basumatary S. 2017. Nutritional value, phytochemicals and antioxidant properties of two wild edible fruits (Eugenia operculata Roxb. and Antidesma bunius L.) from Assam, North-East India. Mediterranean Journal of Nutrition and Metabolism **10**: 29–40.

Ismail M, Bagalkotkar G, Iqbal S, Adamu HA. 2012. Anticancer Properties and Phenolic Contents of Sequentially Prepared Extracts from Different Parts of Selected Medicinal Plants Indigenous to Malaysia. Molecules **17**: 5745–5756.

Isvilanonda S, Bunyasiri I. 2009. Food Security in Thailand: Status, Rural Poor Vulnerability, and Some Policy Options. Kasetsart University, Department of Agricultural and Resource Economics, Working Papers, Thailand.

Ivanišová E, Grygorieva O, Abrahamová V, Schubertova Z, Terentjeva M, Brindza J. 2017. Characterization of morphological parameters and biological activity of jujube fruit (Ziziphus jujuba Mill.). Journal of Berry Research **7**: 249–260.

Jamkhande PG, Suryawanshi VA, Kaylankar TM, Patwekar SL. 2016. Biological activities of leaves of ethnomedicinal plant, Borassus flabellifer Linn. (Palmyra palm): An antibacterial, antifungal and antioxidant evaluation. Bulletin of Faculty of Pharmacy, Cairo University **54**: 59–66.

Jan Y, Malik M, Yaseen M, Ahmad S, Imran M, Rasool S, Haq A. 2019. Vitamin D fortification of foods in India: present and past scenario. The Journal of Steroid Biochemistry and Molecular Biology **193**: (105417) doi: 10.1016/j.jsbmb.2019.105417.

Jayathilake C, Rizliya V, Liyanage R. 2016. Antioxidant and Free Radical Scavenging Capacity of Extensively Used Medicinal Plants in Sri Lanka. Procedia Food Science **6**: 123–126.

Jaysingrao JS, Sunil CN. 2014. Nutritional Assessment of Fruits of Luffa acutangula var. Amara. International Journal of Science and Research **3**: 2205–2207.

Jenjira J, Apidech S, Prasong S. 2013. PHYTOCHEMICAL AND BIOLOGICAL ACTIVITIES IN FRESH JUICE EXTRACTS OF WILD GRAPE (AMPELOCISSUS MARTINI PLANCH.) FRUITS. International journal of Research in Ayurveda & Pharmacy **4**: 337–341.

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

Juwita DA, Mukhtar H, Putri RK. 2020. Uji Antioksidan Ekstrak Etanol Kulit Buah dan Daging Buah Menteng (Baccaurea racemosa (Blume) Mull. Arg.) dengan Metode DPPH (2,2 Diphenyl-1-picrylhydrazyl). SCIENTIA: Jurnal Farmasi dan Kesehatan **10**: 56–62.

Kabera JN, Semana E, Mussa AR, He X. 2014. Plant Secondary Metabolites: Biosynthesis, Classification, Function and Pharmacological Properties. Journal of Pharmacy abd Pharmacology **2**: 377–392.

Kaewseejan N, Puangpronp D, Nakornriab M. 2012. Evaluation of Phytochemical Composition and Antibacterial Property of Gynura procumbens Extract. Asian Journal of Plant Sciences **11**: 77–82.

Kaewseejan N, Siriamornpun S. 2015. Bioactive components and properties of ethanolic extract and its fractions from Gynura procumbens leaves. Industrial Crops and Products **74**: 271–278.

Kalita P, Tag H, Sarma HN, Das AK. 2014. Evaluation of Nutritional Potential of Five Unexplored Wild Edible Food Plants from Eastern Himalayan Biodiversity Hotspot Region (India). International Journal of Nutrition and Food Engineering **8**: 215–218.

Kamel BS, Blackman B. 1982. NUTRITIONAL AND OIL CHARACTERISTICS OF THE SEEDS OF ANGLED LUFFA Luffa acutangula. Food Chemistry **9**: 277–282.

Kanchanapoom T, Kasai R, Yamasaki K. 2002. Phenolic glycosides from Markhamia stipulata. Phytochemistry **59**: 57–563.

Karau GM, Njagi ENM, Machocho AK, Wangai LN, Nthinga MJ. 2015. Chemical Composition and in vitro Antioxidant Activities of Ocimum americanum. Advances in Analytical Chemistry **5**: 42–49.

Keawsa-ard S, Kongtaweelert S. 2012. Antioxidant, Antibacterial, Anticancer Activities and Chemical Constituents of the Essential Oil from Mesua ferrea Leaves. Chiang Mai Journal of Science **39**: 455–463.

Kehrer JP, Klotz L-O. 2015. Free radicals and related reactive species as mediators of tissue injury and disease: implications for Health. Critical Reviews in Toxicology **45**: 765–798.

Khashroom AO, Saewan SA, George SS, Hamad HJ. 2019. Chemical and Microbial Environmental Contaminants in Fruits and Vegetables and their Effects on Health: A Mini Review. IOSR Journal of Environmental Science, Toxicology and Food Technology **13**: 70–76.

Khedari J, Sangprajak A, Hirunlabh J. 2002. Thailand climatic zones. Renewable Energy **25**: 267–280.

Khomdram S, Shantibala Devi GA. 2010. DETERMINATION OF ANTIOXIDANT ACTIVITY AND VITAMIN C OF SOME WILD FRUITS OF MANIPUR. The Biocsan **5**: 501–504.

Khoo HE, Azlan A, Kong KW, Ismail A. 2016. Phytochemicals and Medicinal Properties of Indigenous Tropical Fruits with Potential for Commercial Development. Evidence-Based Complementary and Alternative Medicine **2016**: 1–20.

Kim T-J, Byun J-S, Kwon HS, Kim D-Y. 2018. Cellular toxicity driven by high-dose vitamin C on normal and canc stem cells. Biochemical and Biophysical Research Communications **497**: 347–353.

Kongkachuichai R, Charoensiri R, Yakoh K, Kringkasemsee A, Insung P. 2015. Nutrients value and antioxidant content of indigenous vegetables from Southern Thailand. Food Chemistry **173**: 838–846.

Kriintong N, Katisart T. 2020. In vitro antioxidant and antidiabetic activities of leaf and flower extracts from Bombax ceiba. Pharmacognosy Research **12**: 194–198.

Krongyut O, Sutthanut K. 2019. Phenolic Profile, Antioxidant Activity, and Anti-obesogenic Bioactivity of Mao Luang Fruits (Antidesma bunius L.). Molecules **24**: 1–15.

Kumar A, Patel AA, Gupta VK. 2017[b]. Reduction in oxalate, acridity, phenolic content and antioxidant activity of Amorphophallus paeoniifolius var. Gajendra upon cooking. INTERNATIONAL FOOD RESEARCH JOURNAL **24**: 1614–1620.

Kumar N, Chaiyasut C. 2017. Health Promotion Potential of Vegetables Cultivated in Northern Thailand: A Preliminary Screening of Tannin and Flavonoid Contents, 5α-Reductase Inhibition, Astringent Activity, and Antioxidant Activities. Journal of Evidence-Based Complementary & Alternative Medicine **22**: 573–579.

Kumar Priyanka V, Rajalakshmi R. 2020. PHYTOCHEMICAL SCREENING AND IN-VITRO ANTIOXIDANT ACTIVITY ANALYSIS IN LEAF EXTRACT OF WATER APPLE [SYZYGIUM AQUEUM (BURM. F) ALSTON]. International Journal of Pharmaceutical Sciences and Research **11**: 6350–6357.

Kumar S, Gupta P, Virupaksha Gupta KL. 2013. A Critical Review on Karamarda(Carissa carandas Linn.). International Journal of Pharmaceutical & Biological Archives **4**: 637–642.

Kumar V, Sharma A, Kaur R, Thukral AK, Bhardwaj R, Ahmad P. 2017[a]. Differential distribution of amino acids in plants. Amino Acids **49**: 821–869.

Lasano NF, Hamid AH, Karim R, Dek MSP, Shukri R, Shazini Ramli N. 2019. Nutritional Composition, Anti-Diabetic Properties and Identification of Active Compounds Using UHPLC-ESI-Orbitrap-MS/MS in Mangifera odorata L. Peel and Seed Kernel. Molecules **24**: 1–20.

Lecos C. 1983. Tracking trace minerals. F.D.A. consumer **17**: 16–21.

Lee D-G, Lee Y, Shin H, Kang K, Park J-M, Kim B-K, Kwon O, Lee J-J. 2015. Seizures Related to Vitamin B6 Deficiency in Adults. Journalof Epilepsy Research **5**: 23–24.

Lee SY, Mediani A, Nur Ashikin AH, Azliana ABS, Abas F. 2014. Antioxidant and α-glucosidase inhibitory activities of the leaf and stem of selected traditional medicinal plants. International Food Research Journal **21**: 379–386.

Lehnhardt A, Kemper MJ. 2011. Pathogenesis, diagnosis and management of hyperkalemia. Pediatric Nephrology **26**: 377–384.

Liguory I, Russo G, Curcio F, Bulli G, Aran L, Della-Morte D, Gargiulo G, Testa G, Cacciatore F, Bonaduce D, Abete P. 2018. Oxidative stress, aging, and diseases. Clinical Interventions in Aging **13**: 757–772.

Lim LBL, Chieng HI, Wimmer FL. 2011. Nutrient Composition of Artocarpus champeden and Its Hybrid (Nanchem) in Negara Brunei Darussalam. ASEAN Journal on Science and Technology for Development **28**: 122–138.

Lipinski B. 2011. Hydroxyl Radical and Its Scavengers in Health and Disease. Oxidative Medicine and Cellular Longevity **2011**: 1–9.

Lison D. 2007. Cobalt. Pages 511–528 in Nordberg GF, Fowler BA, Nordberg M, Friberg LT, editors. Handbook on the Toxicology of Metals. Elsevier Inc, United Kingdom.

Liu M et al. 2020. The historical and current research progress on jujube–a superfruit for the future. Horticulture Research **7**: (119) doi: 10.1038/s41438-020-00346-5.

Lopez MJ, Mohiuddin SS. 2021. Biochemistry, Essential Amino Acids. StatPearls Publishing. Available from https://www.ncbi.nlm.nih.gov/books/NBK557845/ (assecced March 2021).

Lunn J, Buttriss JL. 2007. Carbohydrates and dietary fibre. Nutrition Bulletin **32**: 21–64.

Ma Y, He FJ, MacGregor GA. 2015. High Salt Intake. Hypertension **66**: 843–849.

Majid AA, Sarmani S, Yusoff NI, Wei YK, Hamzan F. 1995. TRACE ELEMENTS IN MALAYSIAN MEDICINAL PLANTS. Journal of Radioanalytical and Nuclear Chemistry **195**: 173–183.

Mamta, Misra K, Dhillon GS, Brar SK, Verma M. 2014. Antioxidants. Pages 117–138 in Brar SK, Dhillon GS, Soccol CR, editors. Biotransformation of Waste Biomass into High Value Biochemicals. Springer, New York, NY.

Mani B, Thomas S. 2020. Variation in antioxidant activity at two ripening stages of wild mango, Spondias pinnata (L.f.) Kurz., an underutilized fruit. Plant Science Today **7**: 534–541.

Manikandaselvi S, Vadivel V, Brindha P. 2016. Review on Luffa acutangula L.: Ethnobotany, Phytochemistry, Nutritional Value and Pharmacological Properties. International Journal of Current Pharmaceutical Review and Research **7**: 151–155.

Mann S, Satpathy G, Gupta RK. 2016. Evaluation of nutritional and phytochemical profiling of Baccaurea ramiflora Lour. syn. Bac-caurea sapida (Roxb) Mull Arg fruits. Indian Journal of Traditional Knowledge **15**: 135–142.

Mar WW, Win NN. 2019. INVESTIGATION OF THE PHYSICOCHEMICAL AND BIOACTIVITY PROPERTIES OF Dolichandrone spathacea (Tha khut). Dagon University Commemoration of 25th Anniversary Silver Jubilee Research Journal **9**: 109–115.

Marcason W. 2009. What Is the Açaí Berry and Are There Health Benefits? Journal of the American Dietetic Association **109**: 1968–1968.

Marcus JB. 2013. Culinary Nutrition. Elsevier Inc, United Kingdom.

Mehmood A, Ishaq M, Usman M, Zhao L, Ullah A, Wang C. 2020. Nutraceutical perspectives and value addition of phalsa (Grewia asiatica L.): A review. Journal of Food Biochemistry **44**: (e13228) doi: 10.1111/jfbc.13228.

Meyer-Ficca M, Kirkland JB. 2016. Niacin. Advances in Nutrition **7**: 556–558.

Miller JW, Rucker RB. 2020. Pantothenic acid. Pages 273–287 in Marriott BP, Birt DF, Stallings VA, Yates AA, editors. Present Knowledge in Nutrition. Elsevier Inc, United Kingdom.

Ministry of Public Health. 2017. 5-Year National NCDs Prevention and Control Strategic and Action Plan. Emotion Art Co., Thailand.

Mirfat AHS, Salma I, Razali M. 2016. Natural antioxidant properties of selected wild Mangifera species in Malaysia. Journal of tropical agriculture and food science **44**: 63–72.

Mirończuk-Chodakowska I, Witkowska AM, Zujko ME. 2018. Endogenous non-enzymatic antioxidants in the human body. Advances in Medical Sciences **63**: 68–78.

Mitchell HK, Snell EE, Williams RJ. 1941. THE CONCENTRATION OF "FOLIC ACID". Journal of the American Chemical Society **63**: 2284–2284.

Moussa Z, Judeh ZMA, Ahmed S. 2020. Nonenzymatic Exogenous and Endogenous Antioxidants. Pages 95–116 in Das K, Das S, Biradar MS, Bobbarala V, Tata SS, editors. Free Radical Medicine and Biology. IntechOpen, London, United Kingdom.

Mundaragi A, Devarajan T, Jeyabalan S, Bhat S, Hospet R. 2017[a]. PROXIMATE ANALYSIS AND MINERAL COMPOSITION OF POTENTIAL MINOR FRUITS OF WESTERN GHATS OF INDIA. Scientific Papers. Series A. Agronomy **LX**: 340–346.

Mundaragi A, Devarajan T, Jeyabalan S, Bhat S, Hospet R. 2017[b]. UNEXPLOITED AND UNDERUTILIZED WILD EDIBLE FRUITS OF WESTERN GHATS IN SOUTHERN INDIA. Scientific Papers. Series A. Agronomy **LX**: 326–339.

Murphy E, Williams GR. 2009. Hypocalcaemia. Medicine **37**: 465–468.

Mustafa AA, El-kamali HH. 2019. Chemical Composition of Ocimum americanum In Sudan. Research in Pharmacy and Health Sciences **05**: 172–178.

Nallakurumban B, Suja N, Vijayakumar A, Pushpa G, Geetha PS. 2015. Study on Phytochemical and Antioxidant Properties of Water Apple (Syzygium aqueum) and Chappathikalli (Opuntia ficus-indica). INTERNATIONAL JOURNAL FOR RESEARCH IN EMERGING SCIENCE AND TECHNOLOGY **2**: 18–23.

Nanasombat S, Khanha K, Phan-im J, Jitaied J, Wannasomboon S, Patradisakorn S, Wongsil A. 2012. ANTIMICROBIAL AND ANTIOXIDANT ACTIVITIES OF THAI LOCAL FRUIT EXTRACTS: APPLICATION OF A SELECTED FRUIT EXTRACT, PHYLLANTHUS EMBLICA LINN. AS A NATURAL PRESERVATIVE IN RAW GROUND PORK DURING REFRIGERATED STORAGE. The Online Journal of Science and Technology **2**: 1–7.

Nataraj HN, Murthy RLN, Ramachandra Setty S. 2009. Invitro Quantification of Flavonoids and Phenoliccontent of – Suran. International Journal of ChemTech Research **1**: 1062–1067.

Neto MAM, da Silva Lobato AK, Alves JD, Goulart PFP, Laughinghouse IV HD. 2010. Seed and seedling anatomy in Euterpe oleracea Mart. during the germination process. Journal of Food, Agriculture & Environment **8**: 1147–1152.

Nimni ME, Han B, Cordoba F. 2007. Are we getting enough sulfur in our diet? Nutrition & Metabolism **4**: (24) doi:10.1186/1743-7075-4-24.

Novotny JA, Peterson CA. 2018. Molybdenum. Advances in Nutrition **9**: 272–273.

Nunes PC, Aquino J de S, Rockenbach II, Stamford TLM, Lightfoot DA. 2016. Physico-Chemical Characterization, Bioactive Compounds and Antioxidant Activity of Malay Apple [Syzygium malaccense (L.) Merr. & L.M. Perry]. PLOS ONE **11**: (e0158134) doi: 10.1371/journal.pone.0158134.

Nur AI, Mohd Fadzelly AB, Fazleen Izzany AB, Azlen CR, Norizati M. 2019. Underutilized Mangifera Species (Mangifera caesia, Mangifera quadrifida and Mangifera odorata) from Borneo : A Potential Source of Antioxidant. Journal of Engineering and Applied Sciences **14**: 1169–1177.

Omotosho I. 2019. Plant Sources of Vitamin D and Its Medicinal Application in Sub-Sahara Africa. Pages 430–490 in Zawada Jr. ET, editor. Fads and Facts about Vitamin D. IntechOpen, London, United Kingdom.

Pacei F, Tesone A, Laudi E, Cretti A, Pnini S, Varesco F, Colombo C. 2020. The relevance on Thiamine Evaulation in a Practical Setting. Nutrients **12**: (2810) doi:10.3390/nu12092810.

Paciolla C, Fortunato S, Dipierro N, Paradiso A, De Leonardis S, Mastropasqua L, e Pinto MC. 2019. Vitamin C in Plants: From Functions to Biofortification. Antioxidants **8**: (519) doi:10.3390/antiox8110519.

Padulosi S, Thompson J, Rudebjer P. 2013. Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): needs, challenges and the way forward. Bioversity International, Rome.

Pagare S, Bhatia M, Tripathi N, Pagare S, Bansal YK. 2015. Secondary Metabolites of Plants and their Role: Overview. Current Trends in Biotechnology and Pharmacy **9**: 293–304.

Pandey D, Bajpai A, Pandey H, Pandey Ak. 2015. Bael (Aegle marmelos Correa.). Pages 81-130 in Ghosh SN, Singh A, ThakurA, editors. Underutilized Fruit Crops : Importance & Cultivation. Jaya Publishing House, India.

Pandiselvi P, Manohar M, Thaila M, Sudha A. 2017. PHARMACOLOGICAL ACTIVITY OF Morinda citrifolia L (Noni). Pages 213–237 in Saranraj P, Dire GF, Jayaprakash A, editors. PHARMACOLOGICAL BENEFITS OF NATURAL PRODUCTS. JPS Scientific Publications, Tamil Nadu, India.

Panwar A, Singh Y, Naik B. 2020. Nutritional and pharmacological health benefits of Bombax ceiba L.. The Pharma Innovation Journal 2020 **9**: 392–396.

Pareek S. 2013. Nutritional composition of jujube fruit. Emirates Journal of Food and Agriculture **25**: 463–470.

Parveen K, Khatkar BS. 2015. Physico-chemical properties and nutritional composition of aonla (Emblica officinalis) varieties. International Food Research Journal **22**: 2358–2363.

Pascual JM, Menkes JH. 2015. Menkes Disease and Other ATP7A Disorders. Pages 455–462 in Rosenberg RN, Pascual JM, editors. Rosenberg's Molecular and Genetic Basis of Neurological and Psychiatric Disease. Elsevier Inc, United Kingdom.

Patel R, Rinker L, Peng J, Chilian WM. 2018. Reactive Oxygen Species: The Good and the Bad. Pages 7–20 in Filip C, Albu E, editors. Reactive Oxygen Species (ROS) in Living Cells. IntechOpen, London, United Kingdom.

Payum T, Das AK, Shankar R, Tamuly C, Hazarika M. 2015. Antioxidant Potential of Solanum Spirale Shoot and Berry: a Medicinal Food Plant Used in Arunachal Pradesh. Americal Journal of Pharmtech Research **5**: 308–314.

Peiris KHS. 2007. Baccaurea motleyana (Muell. Arg.) Muell. Arg.. Pages 389-399 in Pushpakumara DKNG, Gunasena HPM, Sing VP, editors. Underutilized Fruit Trees in Sri Lanka. World Agroforestry Center, South Asia Reginal Office, New Delhi, India.

Pem D, Jeewon R. 2015. Fruit and Vegetable Intake: Benefits and Progress of Nutrition Education Interventions- Narrative Review Article. Iranian Journal of Public Health **44**: 1309–1321.

Pennington JAT, Fisher RA. 2009. Classification of fruits and vegetables. Journal of Food Composition and Analysis **22**: S23–S31.

Penniston KL, Tanumihardjo SA. 2006. The acute and chronic toxic effects of vitamin A. The American Journal of Clinical Nutrition **83**: 191–201.

Petrus AJA. 2013. Sauropus androgynus (L.) Merrill-A Potentially Nutritive Functional Leafy-Vegetable. Asian Journal of Chemistry **25**: 9425–9433.

Petrusán J-I, Rawel H, Huschek G. 2016. Protein-rich vegetal sources and trends in human nutrition: A review. Current Topics in Peptide & Protein Research **17**: 1–19.

Pewlong W, Sajjabut S, Eamsiri J, Chookaew S. 2014. Evaluation of Antioxidant activities, Anthocyanins, Total Phenolic Content, Vitamin C Content and Cytotoxicity of Carissa carandas Linn. Chiang Mai University Journal of Natural Sciences **13**: 509–517.

Phadungkit M, Somdee T, Kangsadalampai K. 2012. Phytochemical screening, antioxidant and antimutagenic activities of selected Thai edible plant extracts. Journal of Medicinal Plants Research **6**: 662–666.

Phukan A, Chetia B, Handique JG, Kardong D. 2016. Antimicrobial, Antioxidant Activities and RP-HPLC Analysis of Three Edible Medicinal Plants Olax acuminata, Gnetum gnemon and Rhaphidophora hongkongensis. National Academy Science Letters **39**: 99–102.

Pleńkowska J, Gabig-Cimińska M, Mozolewski P. 2020. Oxidative Stress as an Important Contributor to the Pathogenesis of Psoriasis. International Journal of Molecular Sciences **21**: **(**6206) doi: 10.3390/ijms21176206.

Pludowski P, Holick MF, Grant WB, Konstantynowicz J, Mascarenhas MR, Haq A, Povoroznyuk V, Balatska N, Barbosa AP, Karonova T, Rudenka E, Misiorowski W, Zakharova I, Rudenka A, Łukaszkiewicz J, Marcinowska-Suchowierska E, Łaszcz N, Abramowicz P, Bhattoa HP, Wimalawansa SJ. 2018. Vitamin D supplementation guidelines. The Journal of Steroid Biochemistry and Molecular Biology **175**: 125–135.

Prakash D, Upadhyay G, Gupta C, Pushpangadan P, Singh KK. 2012. Antioxidant and free radical scavenging activities of some promising wild edible fruits. International Food Research Journal **19**: 1109–1116.

Punchay K, Inta A, Tiansawat P, Balslev H, Wangpakapattanawong P. 2020. Nutrient and Mineral Compositions of Wild Leafy Vegetables of the Karen and Lawa Communities in Thailand. Foods **9**: (1748) doi: 10.3390/foods9121748.

Qiu X-L, Guo Y-X, Zhang Q-F. 2018. Chemical profile and antioxidant activity of Gynura bicolor DC. ethanolic extract. International Journal of Food Properties **21**: 407–415.

RA. 1986. Hypercamcaemia. Drugs **31**: 64–74.

Rabeta MS, Nur Faraniza R. 2013. otal phenolic content and ferric reducing antioxidant power of the leaves and fruits of Garcinia atrovirdis and Cynometra cauliflora. International Food Research Journal **20**: 1691–1696.

Rafat A, Philip K, Muniandy S. 2010. Antioxidant Potential and Phenolic Content of Ethanolic Extract of Selected Malaysian Plants. Research Journal of Biotechnology **5**: 16–19.

Reddy PV, Urooj A. 2013. Antioxidant properties and stability of aegle marmelos leaves extracts. Journal of Food Science and Technology **50**: 135–140.

Rigotti A. 2007. Absorption, transport, and tissue delivery of vitamin E. Molecular Aspects of Medicine **28**: 423–436.

Rizzo G, Laganà AS. 2020. A review of vitamin B12. Pages 105–129 in Patel VB, editor. Molecular Nutrition. Elsevier Inc, United Kingdom.

Rodrigues SL, Baldo MP, Machado RC, Forechi L, Molina M del CB, Mill JG. 2014. High potassium intake blunts the effect of elevated sodium intake on blood pressure levels. Journal of the American Society of Hypertension **8**: 232–238.

Rohyani IS, Aryanti E, Suripto S. 2015. Potensi nilai gizi tumbuhan pangan lokal pulau Lombok sebagai basis penguatan ketahanan pangan nasional. PROS SEM NAS MASY BIODIV INDON **1**: 1698–1701.

Royal Thai Embassy. 2021. Thailand in brief. Royal Thai Embassy, Washington D.C. Available from https://thaiembdc.org/about-thailand/thailand-in-brief/ (accessed March 2021).

Rustan AC, Drevon C. 2005. Fatty Acids: Structures and Properties. Pages 1–7 in Wiley J, editor. Encyclopedia of Life Sciences. John Wiley & Sons, Chichester.

Salahuddin MAH, Ismail A, Kassim NK, Hamid M, Ali MSM. 2020. Phenolic profiling and evaluation of in vitro antioxidant, α-glucosidase and α-amylase inhibitory activities of Lepisanthes fruticosa (Roxb) Leenh fruit extracts. Food Chemistry **331**: (127240) doi: 10.1016/j.foodchem.2020.127240.

Salehi B, Martorell M, Arbiser JL, Sureda A, Martins N, Maurya P, Sharifi-Rad M, Kumar P, Sharifi-Rad J. 2018. Antioxidants: Positive or Negative Actors?. Biomolecules **8**: 124–124.

Santosa D, Haresmita PP. 2015. ANTIOXIDANT ACTIVITY DETERMINATION Garcinia dulcis (Roxb.) Kurz, Blumeamollis (D.Don) Merr., Siegesbeckia orientalis L., AND Salvia riparia H.B.K WHICH COLLECTED FROM TAMAN NASIONAL GUNUNG MERAPI USING DPPH (2,2-diphenyl-1-PIKRIL -HIDRAZIL) AND THIN LAYER CHROMATOGRAPHY. Journal of Traditional and Complementary Medicine **20**: 28–36.

Saraswaty V, Ketut Adnyana I, Pudjiraharti S, Mozef T, Insanu M, Kurniati NF, Rachmawati H. 2017. Fractionation using adsorptive macroporous resin HPD-600 enhances antioxidant activity of Gnetum gnemon L. seed hard shell extract. Journal of Food Science and Technology **54**: 3349–3357.

Sarma A, Sarmah P, Kashyap D, Kalita A. 2014. Evaluation of nutraceutical properties and antioxidant activity of Garcinia cowa roxb. ex choisy fruits found in Assam (India). World Journal of Pharmacy and Pharmaceutical Sciences **3**: 853–859.

Satpathy G, Tyagi YK, Gupta RK. 2011. Preliminary evaluation of nutraceutical and therapeutic potential of raw Spondias pinnata K., an exotic fruit of India. Food Research International **44**: 2076–2087.

Saupi N, Zakaria M, Arshad J. 2015. The proximate compositions and mineral contents of Neptunia oleracea Loureiro, an aquatic plant from Malaysia. Emirates Journal of Food and Agriculture **27**: 266–274.

Schellack G, Harirari P, Schellack N. 2015. B-complex vitamin deficiency and supplementation. African Journal of Pharmacy and Pharmacology **82**: 29–32.

Sela I, Meir AY, Brandis A, Krajmalnik-Brown R, Zeibich L, Chang D, Dirks B, Tsaban G, Kaplan A, Rinott E, Zelicha H, Arinos S, Ceglarek U, Isermann B, Lapidot M, Green R, Shai I. 2020. Wolffia globosa–Mankai Plant-Based Protein Contains

Bioactive Vitamin B12 and Is Well Absorbed in Humans. Nutrients **12**: (3067) doi: 10.3390/nu12103067.

Shanbandeh M. 2021[a]. Statista. Statista Inc. Available from https://www.statista.com/statistics/264001/worldwide-production-of-fruit-by-variety/ (accessed February 2021).

Shanbandeh M. 2021[b]. Statista. Statista Inc. Available from https://www.statista.com/statistics/264065/global-production-of-vegetables-by-type/ (accessed February 2021).

Shoubridge EA. 2001. Cytochrome c oxidase deficiency. American Journal of Medical Genetics **106**: 46–52.

Siddhuraju P. 2002. Studies on the antioxidant activity of Indian Laburnum (Cassia fistula L.): a preliminary assessment of crude extracts from stem bark, leaves, flowers and fruit pulp. Food Chemistry **79**: 61–67.

Siddiqi R, Naz S, Asad Sayeed S, Ishteyaque S, Samee Haider M, Mukhtar Tarar O, Jamil K. 2013. Antioxidant Potential of the Polyphenolics in Grewia asiatica, Eugenia jambolana and Carissa carandas. Journal of Agricultural Science **5**: 217–223.

Sies H. 2000. What is Oxidative Stress? Pages 1-8 in KeaneyJr JF, editor. Oxidative Stress and Vascular Disease. Springer US, Boston, MA.

Simandan T, Sun J, Dix TA. 1998. Oxidation of DNA bases, deoxyribonucleosides and homopolymers by peroxyl radicals. Biochemical Journal **335**: 233–240.

Simes DC, Viegas CSB, Araújo N, Marreiros C. 2020. Vitamin K as a Diet Supplement with Impact in Human Health: Current Evidence in Age-Related Diseases. Nutrients **12**: (138) doi: 10.3390/nu12010138.

Singh A, Soni A, Changani M, Choksi H. 2020[a]. Vitamin D: role of vitamin D in human health beyond skeleton. International Journal of Advances in Medicine **7**: 344–353.

Singh A, Wadhwa N. 2012. Osmotic dehydration of Amorphophallus paeoniifolius slices & it's phyto-chemical investigation. International Journal of Pharmacy & Life Sciences **3**: 1797–1801.

Singh DR, Singh S, Salim KM, Srivastava RC. 2011. Estimation of phytochemicals and antioxidant activity of underutilized fruits of Andaman Islands (India). International Journal of Food Sciences and Nutrition **63**: 446–452.

Singh P, Kesharwani RK, Keservani RK. 2017. Protein, Carbohydrates, and Fats. Pages 103–115 in Bagchi D, editor. Sustained Energy for Enhanced Human Functions and Activity. Elsevier, United Kingdom.

Singh S, Bajpai M, Mishra P. 2020[b]. Pharmacognostical evaluation of indigenous herbal drug: Carissa carandas Linn. fruit. Annals of Phytomedicine: An International Journal **9**: 263–270.

Singthong J, Oonsivilai R, Oonmetta-aree J, Ningsanond S. 2014. BIOACTIVE COMPOUNDS AND ENCAPSULATION OF YANANG (TILIACORA TRIANDRA) LEAVES. African Journal of Traditional, Complementary and Alternative Medicines **11**: 76–84.

Siram K, Habibur Rahman SM, Balakumar K, Duganath N, Chandrasekar R, Hariprasad R. 2019. Pharmaceutical nanotechnology: Brief perspective on lipid drug delivery and its current scenario. Pages 91–115 in Grumezescu AM, editor. Biomedical Applications of Nanoparticles. Elsevier, United Kingdom.

Sirichamorn Y. 2014. Species diversity of calciphilous Derris (Fabaceae) in Thailand. Thai Forest Bulletin **42**: 105–152.

Slezák J, Kura B, Frimmel K, Zálešák K, Ravingerová T, Vinczenczová C, Okruhlicová L, Tribulová N. 2016. Preventive and Therapeutic Application of Molecular Hydrogen in Situations With Excessive Production of Free Radicals. Physiological Research **65**: 11–28.

Sloan S, Jenkins CN, Joppa LN, Gaveau DLA, Laurance WF. 2014. Remaining natural vegetation in the global biodiversity hotspots. Biological Conservation **177**: 12–24.

Smith C, Song W. 1996. Comparative nutrition og pathognic acid. The Journal of Nutritional Biochemistry **7**: 312–321.

Somasundaram N, Wijeyarathne C, Rajaratnam H, Katulanda P, Bulugahapitiya U, Siyambalapitiya S, Antonypillai C, Sumanathilake M, Garusinghe C, Muthukuda D et al. 2014. Sodium Disorders: Hyponatraemia. Sri Lanka Journal of Diabetes Endocrinology and Metabolism **3**: 114–122.

Somdee T, Mahaweerawat U, Phadungkit M, Yangyuen S. 2016. Antioxidant Compounds and Activities in Selected Fresh and Blanched Vegetables from Northeastern Thailand. Chiang Mai Journal of Science **43**: 834–844.

Somsub W, Kongkachuichai R, Sungpuag P, Charoensiri R. 2008. Effects of three conventional cooking methods on vitamin C, tannin, myo-inositol phosphates contents in selected Thai vegetables. Journal of Food Composition and Analysis **21**: 187–197.

Srithi K, Trisonthi C, Wangpakapattanawong P, Srisanga P, Balslev H. 2012. Plant Diversity in Hmong and Mien Homegardens in Northern Thailand. Economic Botany **66**: 192–206.

Stabler SP. 2013. Vitamin B12 deficiency. New England Journal of Medicine **368**: 149–160.

Steinberg F, Rucker R, Ye L, Eitenmiller R. 2005. The Water-Soluble Vitamins. Pages 10-1–10-15 in Hui YH, Sherkat F, editors.
Handbook of Food Science, Technology, and Engineering - 4 Volume Set. Taylor & Francis Group, Boca Raton.

Stratil P, Kubáň V. 2018. Reaktivní kyslíková radikály, přírodní antioxidanty a jejich zdravotní účinky. 2 THETA, Český Těšín.

Subhadrabandhu S. 2001. UNDER-UTILIZED TROPICAL FRUITS OF THAILAND. Food and Agriculture oragnization of the United Nations, Rome.

Subhasree B, Baskar R, Laxmi Keerthana R, Lijina Susan R, Rajasekaran P. 2009. Evaluation of antioxidant potential in selected green leafy vegetables. Food Chemistry **115**: 1213–1220.

Sukum P, Narongchai P, Boonyawan D, Narongchai S, Tippawan U. 2019. Determination of Elements in Gymnema inodorum Lour by Particle Induced X-Ray Emission (PIXE). Biological Trace Element Research **192**: 330–335.

Sundriyal M, Sundriyal RC. 2001. Wild edible plants of the Sikkim Himalaya: Nutritive values of selected species. Economic Botany **55**: 377–390.

Supriatno, Lelifajri. 2002. Effect of sequential extraction on total phenolic content (TPC) and antioxidant activities (AA) of Luffa acutangula Linnaeus dried pulps. AIP Conference Proceedings **2002**: (020062) doi: 10.1063/1.5050158.

Suriyaphan O. 2014. Nutrition, Health Benefits and Applications of Pluchea indica (L.) Less Leaves. Mahidol University Journal of Pharmaceutical Sciences **41**: 1–10.

Susylowati D, Takarina ND. 2019. Phytochemistry screening and total flavonoid test on plants associated mangrove (Pluchea indica and Sesuvium portuculastrum Leafs) at Blanakan, Subang, West Java. AIP Conference Proceedings **2168**: (020084) doi: 10.1063/1.5132511.

Suwannasom N, Kao I, Pruß A, Georgieva R, Bäumler H. 2020. Riboflavin: The Health Benefits of a Forgotten Natural Vitamin. International Journal of Molecular Sciences **21**: (950) doi:10.3390/ijms21030950.

Tahiliani AG, Beinlich CJ. 1991. Pantothenic Acid in Health and Disease. Vitamins & Hormones **46**: 165–228.

Tangkanakul P, Trakoontivakorn G, Jariyavattanavijit C. 2005. Extracts of Thai Indigenous Vegetables as Rancid Inhibitor in a Model System. Kasetsart Journal : Natural Science **39**: 274–283.

Tantipisanuh N, Savini T, Cutter P, Gale GA. 2016. Biodiversity gap analysis of the protected area system of the Indo-Burma Hotspot and priorities for increasing biodiversity representation. Biological Conservation **195**: 203–213.

Thailand Foundation, Ministry of Foreign Affairs of Thailand. 2014. Secrets to Thai Cooking. Thailand Foundation and Ministry of Foreign Affairs of Thailand, Thailand.

Tharanathan RN, Gudipati M, SalimathV,Raghavendra Rao MR. 1987. Plant carbohydrates - An overview. Proceedings of the Indian Academy of Sciences – Section A Part 3 Mathematical sciences **97**: 81–155.

Thompson FE, Willis GB, Thompson OM, Yaroch AL. 2011. The meaning of 'fruits' and 'vegetables'. Public Health Nutrition **14**: 1222–1228.

Thomson CD. 2013. Selenium. Pages 186–192 in Caballero B, editor. Encyclopedia of Human Nutrition. Elsevier Inc, United Kingdom.

Tilaar M, Wih WL, Ranti AS, Wasitaatmadja SM, Suryaningsih, Junardy FD, Maily. 2008. Review of Lansium domesticum Corrêa and its use in cosmetics. Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas **7**: 183–189.

Tisadondilok S, Senawong T. 2018. Antioxidant activities and anticancer screening of ethanolic extracts from Baccaurea macrophylla Muell and Elateriospermum tapos Blume. Journal of Thai Interdisciplinary Research **12**: 11–18.

Tontisirin K, Chavasit V, Parinyasiri T, Ditmetharoj M, Photi J, Intaraluk P, Kittiprapas S. 2013. Country Policy Analysis (Nutrition Impact of Agriculture and Food Systems – Thailand). 2013. UN System Standing Committee on Nutrition country study for the second International Conference on Nutrition, Thailand.

Tordoff AW, Baltzer MC, Fellowes JR, Pilgrim JD, Langhammer PF. 2012. Key Biodiversity Areas in the Indo-Burma Hotspot: Process, Progress and Future Directions. Journal of Threatened Taxa **04**: 2779–2787.

Traber MG, Manor D. 2012. Vitamin E. Advances in Nutrition **3**: 330–331.

Turck D, Bresson J-L, Burlingame B, Dean T, Fairweather-Tait S, Heinonen M, Hirsch-Ernst KI, Mangelsdorf I, McArdle HJ, Naska A et al. 2017. Dietary reference values for vitamin K. ESFA Journal **15**: (e04780) doi: 10.2903/j.efsa.2017.4780.

Turck D, Castenmiller J, de Henauw S, Hirsch-Ernst KI, Kearney J, Knutsen HK, Maciuk A, Mangelsdorf I, McArdle,HJ, Pelaez C et al. 2019. Dietary reference values for chloride. EFSA Journal **17**: (e05779) doi: 10.2903/j.efsa.2019.5779.

Tyug TS, Johar MH, Ismail A. 2010. Antioxidant Properties of Fresh, Powder, and Fiber Products of Mango (Mangifera Foetida) Fruit. International Journal of Food Properties **13**: 682–691.

US Institute of Medicine. 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academies Press (US), Washington (DC).

US Office of Dietary Supplements. 2020. Boron. U.S. Department of Health & Human Services, United States of America. Available from https://ods.od.nih.gov/factsheets/Boron-HealthProfessional/#en8 (accessed January 2021).

Useful Tropical Plant Database. 2014. Useful Tropical Plants Database 2014 by Ken Fern. Available from http://tropical.theferns.info/ (accessed April 2021).

Uttara B, Singh AV, Zamboni P, Mahajan RT. 2009. Oxidative Stress and Neurodegenerative Diseases: A Review of Upstream and Downstream Antioxidant Therapeutic Options. Current Neuropharmacology **7**: 65–74.

Vainio H, Bianchini F. 2003. Fruit and vegetables. IARCPress, Lyon.

Valavanidis A, Vlachogianni T, Fiotakis K, Loridas S. 2013. Pulmonary Oxidative Stress, Inflammation and Cancer: Respirable Particulate Matter, Fibrous Dusts and Ozone as Major Causes of Lung Carcinogenesis through Reactive Oxygen Species Mechanisms. International Journal of Environmental Research and Public Health **10**: 3886–3907.

Valíček P. 2002. Užitkové rostliny tropů a subtropů. Vyd. 2., upr. a dopl. Academia, Praha.

Venthodika A, Chhikara N, Mann S, Garg MK, Sofi SA, Panghal A. 2020. Bioactive compounds of Aegle marmelos L., medicinal values and its food applications: A critical review. Phytotherapy Research **34**: 1–21.

Vijayakumari, Vengaiah PC, Kiranmayi P. 2014. Physicochemical and functional characteristics of powder prepared from palmyra fruit pulp (Borassus flabellifer L.). International Journal of Current Microbiology and Applied Sciences **3**: 352–356.

Vittaya L, Khongsai S, Ui-eng J, Chalad C, Leesakul N. 2019. Effect of total phenolic and flavonoid contents of Ampelocissus martinion radical scavenging and antibacterial activities. Agriculture and Natural Resources **53**: 154–160.

Vrolijk MF, Opperhuizen A, Jansen EHJM, Hageman GJ, Bast A, Haenen GRMM. 2017. The vitamin B6 paradox: Supplmentation with high concentrations of pyridoxine leads to decreased vitamin B6 function. Toxicology in Vitro **44**: 206–212.

Vu DT, Nguyen TA. 2017. The neglected and underutilized species in the Northern mountainous provinces of Vietnam. Genetic Resources and Crop Evolution **64**: 1115–1124.

Wang M, Fu Y, Liu H. 2015. Nutritional status and ion uptake response of Gynura bicolor DC. between Porous-tube and traditional hydroponic growth systems. Acta Astronautica **113**: 13–21.

Wang Q, Wang Y, Ju P, Luo S. 2008. The Phenolic Components from Saurauia napaulensis. Natural Product Research & Development **20**: 641–643.

Weather Atlas. 2021. Thailand climate. Yu Media Group d.o.o. Available from https://www.weather-atlas.com/en/thailand-climate (accessed March 2021).

WebMD. 2021. PARA-AMINOBENZOIC ACID (PABA). WebMD LLC. Available from https://www.webmd.com/vitamins/ai/ingredientmono-1004/para-aminobenzoic-acid-paba (accessed February 2021).

Weisinger JR, Bellorín-Font E. 1998. Magnesium and phosphorus. The Lancet **352**: 391–396.

World Health Organization and Food and Agriculture Organization of the United Nations. 2004. Vitamin and mineral requirements in human nutrition Second edition. WHO and FAO, Rome.

World Health Organization. 2009. Calcium and Magnesium in Drinking-water : Public health significance. World Health Organization, Geneva.

Yadav A, Kumari R, Yadav A, Mishra JP, Srivatva S, Prabha S. 2016. Antioxidants and its functions in human body - A Review. Research in Environment and Life Sciences **9**: 1328–1331.

Yang Q, Cogswll Me, Hamner HC, Carriquiry A, Bailey LB, Pfeiffer CM, Berry RJ. 2010. Folic acid source, usual intake, and folate and vitamin B-12 status in US adults: National Health and Nutrition Examination Survey (NHANES) 2003–2006. The American Journal of Clinical Nutrition **91**: 64–72.

Yussif MN. 2019. Vitamin C. Pages 1–28 in LeBlanc JG, editor. Vitamin C - an Update on Current Uses and Functions. IntechOpen, London, United Kingdom.

Zabidi AR, Mohd Razif MA, Ismail SN, Sempo MW, Yahaya N. 2020. Antimicrobial and Antioxidant Activities in 'Beluntas' (Pluchea indica), Turmeric (Curcuma longa) and Their Mixtures. Sains Malaysiana **49**: 1293–1302.

Zaja-Milatovic S, Gupta RC. 2020. Exitotoxicity, oxidative stress, and neuronal injury. Pages 795–806 in Gupta RC, editor. Toxicology of Chemical Warfare Agents. Elsevier Inc., United Kingdom.

Zempleni J, Kuroishi T. 2012. Biotin. Advances in Nutrition **3**: 213–214.

Zengin G et al. 2019. Comprehensive approaches on the chemical constituents and pharmacological properties of flowers and leaves of American basil (Ocimum americanum L). Food Research International **125**: (108610) doi: 10.1016/j.foodres.2019.108610.

Zimmermann MB, Jooste PL, Pandav CS. 2008. Iodine-deficiency Disorders. The Lancet **372**: 1251–1262.

6.1. References of figures

F.O.O.D. 2019. Thajské rýžové nudle Pad Thai. Recepty.cz. Available from https://www.recepty.cz/recept/thajske-ryzove-nudle-pad-thai-163733 (accessed March 2021).

Our Tropical Soil. 2019. Noni – Morinda citrifolia. Our Tropical Soil. Available from https://ourtropicalsoil.com/2019/01/22/noni/ (accessed March 2021).

Tantipisanuh N, Savini T, Cutter P, Gale GA. 2016. Biodiversity gap analysis of the protected area system of the Indo-Burma Hotspot and priorities for increasing biodiversity representation. Biological Conservation **195**: 203–213.

Useful Tropical Plant Database. 2014. Useful Tropical Plants Database 2014 by Ken Fern. Available from http://tropical.theferns.info/ (accessed April 2021).

Wiens, M. 2021. Thai Food TV Show in Thailand. Migrationology. Available from https://migrationology.com/thai-food-tv-show-thailand/ (accessed March 2021).

Appendices

List of the Appendices:

Appendices: Photos of the most promising Thai underutilized species

Appendix I. ***Aegle marmelos:*** (Useful Tropical Plant Database 2014)

Appendix II. ***Sesbania grandiflora:*** (Useful Tropical Plant Database 2014)

Appendix III. ***Spondias pinnata:*** (Useful Tropical Plant Database 2014)

Appendix IV. ***Ziziphus jujuba:*** (Useful Tropical Plant Database 2014)