

## Recent Trends in Functional Foods and Nutraceuticals as Health-Promotive Measures: A Review

Uthpala Bulathgama<sup>1</sup>, Nilantha Lakshman<sup>2\*</sup> and Vajira. P. Bulugahapitiya<sup>3</sup>

### Abstract

Non-Communicable Diseases (NCDs) have become a major health concern worldwide. The global death percentage caused by NCDs is reported to be 70% of the total deaths. Currently, there is a significant concern about herbal applications in improving people's lifestyles to mitigate the risk of NCDs, and food product development with an herbal context is considered more impactful. Plant/herbal materials have been used in traditional medicine since ancient times due to the nutraceutical properties of secondary plant metabolites. These are known to exert several health-promoting effects such as antioxidant, anti-cancer, anti-lipidemic, anti-hyperglycemic, etc. properties. Therefore, modern society is concerned more about adopting to pharmaceuticals and diet interventions of natural-origin to mitigate health conditions associated with NCDs. Those interventions are, in most cases, termed functional foods and/or nutraceuticals. Thus, a substantial global market opportunity has been relieved for herbal functional foods and nutraceuticals, recently. Therefore, this paper provides a narrative review on the global burden caused by the NCDs, and the deviation of consumer trends towards more natural and herbal oriented functional foods in overcoming those risks. Furthermore, such trends are predicted to rise drastically in upcoming years in the regions around the globe with significant generation of revenue. This review further elaborates on pharmacological and health benefits of herbal materials that could be used in developing functional foods and/or nutraceuticals. In addition, current and prospective functional foods and nutraceuticals that have been developed with herbal origins in recent research across the globe are presented here with their respective health-promoting effects. The food categories currently being developed into functional foods are mostly being, but not limited to, functional beverages, functional teas, functional snacks/starchy foods, and functional confectioneries. The physiological benefits expected by these functional foods and nutraceuticals include, prevention of hyperglycaemia, cardiovascular disease, hypertension, cancers, hypercholesterolemia, etc. This review would provide a brief but informative background for future researchers, who would carry out research on New Product Development (NPD) on functional foods and nutraceuticals of herbal origin.


**Keywords:** Functional Foods, Herbal, Non-Communicable Diseases, Nutraceuticals

<sup>1</sup>Department of Bio-systems Technology, Faculty of Technology, University of Ruhuna, Kamburupitiya, Sri Lanka.

<sup>2</sup>Department of Food Science and Technology, Faculty of Agriculture, University of Ruhuna, Kamburupitiya, Sri Lanka.

<sup>3</sup>Department of Chemistry, Faculty of Science, University of Ruhuna, Matara, Sri Lanka.

\* Correspondence: nilanthal@fst.ruh.ac.lk

 <https://orcid.org/0000-0002-1002-6664>



© The Author(s). This article is published under the Creative Commons Attribution License (CC 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

There is a huge health concern all around the world despite the country's status on Non-Communicable Diseases (NCDs). With the advancement of science, much research has been conducted and several remedies were found to treat communicable or acute diseases such as infections to date. Pharmaceuticals play a vital role in this scenario. However, the global burden due to NCDs and chronic diseases captures the attention of many medical researchers as they are being responsible for more than 70% of the annual global deaths and due to lack of remedial measures. The fact that those diseases highly depend on food and lifestyle, and the uprising demand for foods and drugs of natural origin, current research trends are focused toward functional foods and nutraceuticals.

### Global Burden of Non-Communicable Diseases

Globally, NCDs have been rising continuously in recent years, despite the countries or regions. As reported in 2010, in 2005, the NCDs caused about 35 million deaths around the world, which accounts for 60% of all deaths worldwide. It is estimated to grow by 17% within the next 10 years [1]. At present, the global death percentage is reported to be over 70% of all deaths and is around 41 million people per year, which even exceeds the expected rise of the death percentage according to the latest statistics published by the World Health Organization (WHO) in 2020 [2]. This regular increase in death rates caused by NCDs has influenced the United Nations to discuss "Non-Communicable Diseases" in three out of the very few high-level meetings on health-related issues on 19-20<sup>th</sup> September, 2011 [3], 10-11<sup>th</sup> July, 2014 [4] and 27<sup>th</sup> September 2018 [5].

NCDs are also known as chronic diseases and tend to be of long duration. These result from a combination of genetic, physiological, environmental, and behavioural factors [6]. Several health

conditions are categorized as NCDs. According to previous researches, it has been determined that four major disease clusters, namely cardiovascular diseases, cancers, pulmonary diseases, and diabetes, are responsible for 80% of NCD-related deaths [3, 7]. Other than these, several other diseases that are not transmitted from person to person and do not cause acute infections that are classified as NCDs, such as asthma, digestive diseases, neurologic disorders, mental and behavioural disorders, kidney diseases, gynecologic disorders, hemoglobinopathies, sense-organ, and oral disorders, bear a significant burden [3]. The WHO has identified several risk factors for NCDs. Among them, depression, impaired glucose tolerance, high cholesterol, high blood pressure, obesity, unhealthy diet, smoking, physical inactivity, and excess alcohol consumption have been identified to be more critical [8].

Further, many systematic reviews have summarized the most influential risk factors of NCDs and, therefore, the strongest preventive factors cross-linked with the five major NCD categories (dementia, diabetes, stroke, coronary heart disease, and cancer) are unhealthy diet, physical inactivity, and smoking [3, 9]. As a healthier diet is a major preventive factor and/or risk factor for NCDs, a growing interest towards healthy food consumption has captured massive awareness throughout the globe. Plant-based products such as functional foods and/or nutraceuticals have emerged as a high-impact preventive measure for NCDs across the globe [7-9].

### Functional Foods and Nutraceuticals

Functional foods and/or nutraceuticals are considered beneficial in preventing or treating diseases or improving health conditions, other than their usual nutritional value [10]. However, the terms "Functional foods" and "Nutraceuticals" have confusion in their definitions and are not defined well to separate between the two terms and also with terms such as "Conventional foods" and

“Pharmaceuticals”. Thus, it has been given several similar, yet non-unified definitions in many research and review publications [11]. Generally, functional foods and nutraceuticals are considered to occupy a grey area between food and drugs [12]. The concept defining and initiation of these terms happened in the early 1980s by Japanese scientists, and the term “Nutraceuticals” was also formed in 1984 by Dr. De Felice by coining “Nutrition and Pharmaceuticals” [12-18].

Functional foods are defined by "Health Canada" as foods that resemble traditional foods, while demonstrating physiological properties. Meanwhile, nutraceuticals are derived from foods and presented in a non-food matrix but in medicinal forms such as capsules, tablets, and so on, and used to demonstrate physiological benefits in a concentrated form [10-11, 19-22]. In many studies and writings, the definition of nutraceuticals is slightly varying. They are known as products with physiological benefits or those that provide protection against chronic diseases, derived from plant, animal, or marine sources or produced from processing plant material [18]. According to Pandey *et al.* [12], aside from the physiological benefits they provide, nutraceuticals are not traditionally recognized as nutrients, and Murthy [23] claims nutraceuticals are closely resembling drugs, except for their natural origin [12, 23]. However, there are still many definitions, which indicate nutraceuticals as foods or parts of foods [23, 24].

The European Union has suggested a working definition for functional foods in their Concerted Action on Functional Food Science in Europe (FuFoSE) as, when a food product has beneficial effects on one or more functions of the human organism; either improving the general and physical conditions or/and decreasing the risk of the evolution of diseases along with its basic nutritional impact. However, this definition limits its consumption format and dosage to the conventional food types in usual dietetic

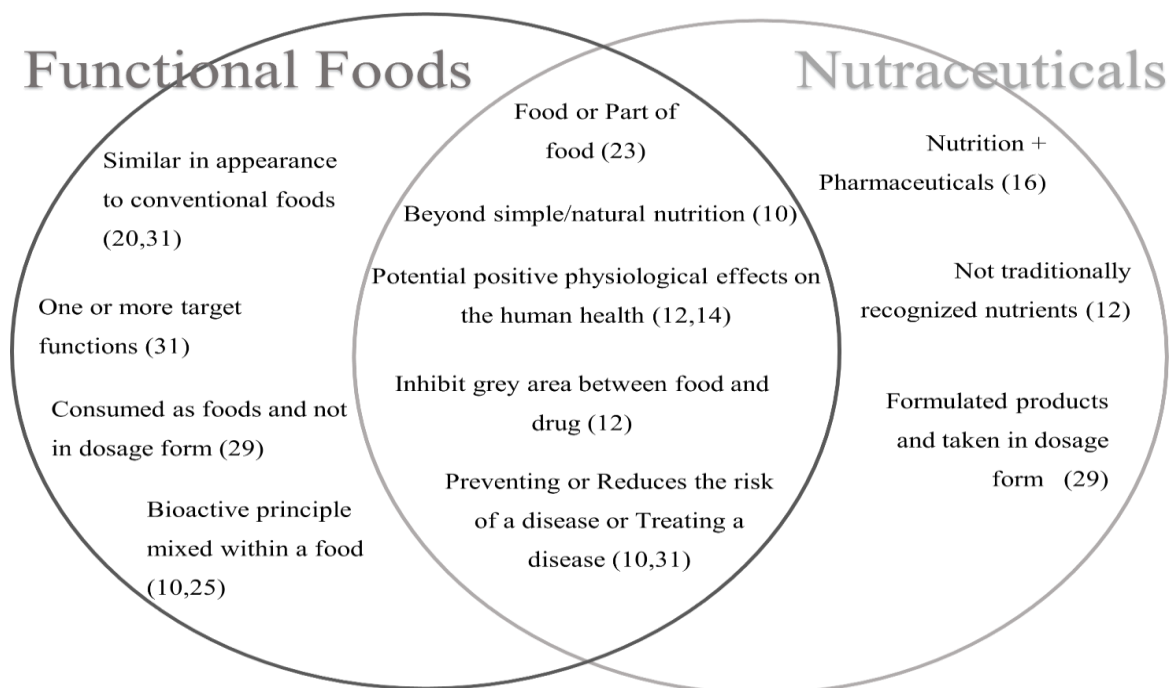
proportions [13, 25, 26]. However, this is controversial with the Japanese definition derived for Food for Specified Health Use (FOSHU), including the forms of tablets and capsules too, where health claims or benefits remain a common requirement [13]. Japan was the first country to have functional foods and nutraceutical regulations, and Japanese food regulations for health claims have been greatly clarified. So far, over 200 products are in the market under this FOSHU category [10, 15, 27-29]. The USA does not have a well-defined and regulated framework for defining or claiming functional foods and nutraceuticals. They are either categorized as foods or drugs, and the products are usually regulated by the food laws of the United States [30].

### **Key Concepts of Functional Foods and Nutraceuticals**

With this ambiguity of definitions, identifying the key properties of both functional foods and nutraceuticals is important in designing and developing novel functional foods/ nutraceuticals [31]. The major concepts covered by the definitions for both terms “Functional foods” and “Nutraceuticals” are summarized in a Venn diagram (Figure 1).

Apart from the above summarized key factors, Doyon & Labrecque [11] have identified four major concept areas covered by most of these definitions. Those are health benefits, nature of the food, level of function, and consumption pattern.

Health Benefits: Functional foods or nutraceuticals, have been identified and claimed for several health benefits in preventing, reducing the risk, or treating a disease and/or unfavourable health condition. Strong literature evidence was found on the ability of functional foods and nutraceuticals in preventing and treating several types of cancers in combination effects such as antioxidant activity, increased detoxifying enzyme activity, maintenance of DNA repair, and effects on cell differentiation



**Figure 1:** Key Concepts Covered by Many Definitions on the Terms, "Functional Foods" and "Nutraceuticals"

etc. [20, 32-34]. Cardiovascular diseases along with cross-linking health conditions; obesity, high blood cholesterol, high blood pressure, and type 2 diabetes, are supported by functional foods and nutraceuticals through many mechanisms including lowering blood lipid levels, decreasing plaque formation, reducing lipoprotein oxidation, improving arterial compliance, scavenging free radicals, and inhibiting platelet aggregation [20, 35-37]. Continuous consumption of plant-derived functional foods is supportive in preventing and managing type 2 diabetes with their antioxidant, anti-inflammatory, insulin sensitivity, and anti-cholesterol functions due to the content of nutraceuticals including; polyphenols, terpenoids, flavonoids, alkaloids, sterols, pigments, and unsaturated fatty acids [38-40].

**Nature of Food:** There is no box-framed definition for functional foods and nutraceuticals and the confusion is caused by aligning terms such as designer foods, dietary

supplements, enhanced foods, etc. with functional foods. The nature of the food was also not defined without conflicts [41, 42]. Shinde *et al.* [43] categorized nutraceuticals in three major arenas regarding their nature, where dietary supplements are vitamins and minerals or botanicals like Ginseng, Ginkgo Biloba, Saint John's Wort, etc., functional foods to be a part of the usual diet with effects beyond traditional nutrition; and medicinal foods to be used in preventing or treating disease [43]. Although in general, functional foods are considered to look like conventional food and nutraceuticals to be in drug-like form, this might change from one product to another [29].

**Level of Function:** Functional foods or nutraceuticals are being used in several stages of functionality, where they could either be enhancing healthiness, preventing the occurrence of a disease or illness, reducing the risk of such illness, or even treating the diseases or illnesses. The benefits of

functional foods and nutraceuticals may therefore include increasing the health value of the diet, increasing life expectancy; avoiding unfavourable medical conditions, imparting physiological benefits, being more natural with fewer side effects; and catering to special needs for dietary complexities such as celiac, lactose intolerant, or elderly patients [42].

**Consumption Pattern:** Functional foods and nutraceuticals are consumed similarly according to some limitations as they are food and/or part of food [23]. Furthermore, some consider a functional food to be one developed with scientific intelligence; when the functional food aids in the prevention or treatment of a disease other than anaemia, it is referred to as a nutraceutical [12, 16]. Also, the dosage or the consumption portions are different from each other as some definitions find nutraceuticals to be in dosage specified form while functional foods are to be taken in usual dietetic portions [29].

#### **Nutraceutical Properties of Herbal Material**

Traditional medicine, or folk medicine, has been used for supporting and curing NCDs since ancient times. The major active ingredients used in such medicinal approaches are herbal materials [44]. Although the available and recognized herbs vary region-wise, the utilization of herbals in NCDs has become prominent and captured global attention [45].

Numerous research and reviews have been carried out to identify the herbs and active compounds of herbs that are helpful in supporting many health conditions, which could ultimately be used in developing functional foods and/or nutraceuticals.

Moreover, it is evident that some herbal components are acting as functional foods even in their pure form and could be consumed as it is or with minimal processing and with an evident beneficial physiological impact. Examples: Berries, Cinnamon,

Turmeric, Ginseng, Tomatoes, Soybeans, Oats, Psyllium, Flaxseed, Garlic, Grapes, and some nuts etc. [35, 39, 46]. Apart from these, there are many examples of products which incorporate refined functional compounds from plant derivatives [47, 48] and combined functional foods that show enhanced functionality or synergic effects [49, 50].

#### **Types of Herbal Functional Compounds Present in Functional Foods/Nutraceuticals**

A vast array of biologically active secondary metabolites take part in plant-derived functional foods and nutraceuticals.

- *Polyphenols:* These are a class of plant secondary metabolites that contain over 8000 compounds and protect plants from UV radiation, oxidants, and infections. They are found in whole plant foods such as fruits, vegetables, whole grains, cereals, legumes, tea, coffee, wine and cocoa [51, 52]. The main classes of polyphenols include phenolic acids, flavonoids, stilbenes, and lignins [51]. Epidemiological studies and associated meta-analyses in recent history strongly suggest that long-term consumption of a polyphenol-rich diet supports in management of many NCDs including cancer, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases [51, 53, 54]. Cardioprotective effect [55-57], anti-cancer effect [58], anti-diabetic effect [59], and neuroprotective effects [60-63] are some major beneficial effects of these polyphenols in human health.
- *Isoflavonoids:* These are also a class of phenolic phytochemicals that includes the major compounds genistein and daidzein. This class is recognized for preventing and treating cancer and osteoporosis. In particular, Genistein imparts cancer-preventive activity against colon cancer in vitro. The most predominant dietary source of isoflavones is Soybeans [64, 65].

- *Phytoestrogens*: This is a nonsteroidal phytochemical group that has a quite similar structure and function to the oestrogen hormone. And phytoestrogens show antioxidant properties due to their polyphenolic structure and anti-carcinogenic properties due to steroid metabolism or enzyme detoxification. Furthermore, they have a favourable effect on calcium transportation and lipid profiles [64, 66, 67].
- *Terpenoids*: These compounds also show cancer-preventive properties and are the largest class of phytonutrients found in green foods and grains. The most studied terpenoids are tocotrienols and tocopherols, commonly found in whole grains [65].
- *Carotenoids*: The Carotenoids are pigmented phytonutrients that can be divided into two major groups: carotenes and xanthophylls. Carotenes provide protection against uterine, prostate, breast, colorectal, lung, and digestive tract cancers, while xanthophylls provide protection for other antioxidants and offer tissue-specific protection. This subclass of phytochemicals is common in yellow-red fruits and vegetables [64, 68, 69].
- *Phytosterols*: An important subclass of phytonutrients. They are beneficial mostly in managing cholesterol levels in humans, as these compounds compete with cholesterol in the gut to eliminate cholesterol from the body without absorption [64, 70].
- *Glucosinolates*: This is another cancer-preventive phytochemical class and are present in cruciferous vegetables such as broccoli and cauliflower sprouts [64].
- *Polysaccharides*: These comprise of a large group of phytochemicals that provides many characteristics in food production like thickening, binding, bulking, etc.

and are present in mushrooms, fruits and vegetables, legumes, cereals, and grains like oats and barley. These are responsible for many physiological functions, such as preventing cancer, obesity, and cardiovascular disease, normalizing blood pressure, balancing blood sugar levels, etc. [64, 71].

### **Herbs with Nutraceutical Potential**

Listed below (see Table 1) are some herbs with potential nutraceutical properties due to their bioactive secondary plant metabolites and their respective health benefits. Other than the few summarized in Table 1, a strong herbal profile is important in supporting NCDs or chronic diseases, where some are still underutilized and under-recognized.

Biologically relevant compounds in action for reducing the risk of NCDs and treating NCD conditions are phytochemicals present in herbs, where the antioxidants capture the highest capacity and importance, as most chronic diseases, such as cardiovascular diseases, are associated with a high level of oxidative stress and could be managed through the antioxidant activity of plant compounds [42, 124]. Table 2 shows some important and recognized functional (bioactive) compounds derived from herbal materials [47, 99, 125-129].

### **Product Development of Functional Foods and Nutraceuticals**

#### ***Global Market and Demand***

The development of functional foods or nutraceuticals is considered to attract a long-term market value as their demand rises by 6-10% every year [11, 43]. Additionally, functional foods are typically priced 30-500% above comparable conventional foods [130]. According to the data taken in 2008, the global functional food market falls into the range of EUR 30-60 billion. It is reported that the functional foods and nutraceutical market in the United States were 250 billion US dollars in 2014 [43]. Although the European market is less developed compared to the USA and Japan, it still has a functional food market that

**Table 1:** Herbal Materials and their Secondary Metabolites that Impart Nutraceutical Properties

No	Potential Herb	Active Compounds	Supporting NCDs/ Beneficial Action
1	Aloe vera <i>Aloe barbadensis</i>	Aloins Aloesin	Dilates capillaries [72], Anti-inflammatory effect [72-77], Anti-diabetic effect [72-77]
2	St John's-wort <i>Hypericum perforatum</i>	Hypericin Hyperforin	Antidepressant effect [78, 79]
3	Turmeric <i>Curcuma longa</i>	Curcumin	Anticancer effect [24], Anti-inflammatory effect, Antiarthritic effect [80, 81]
4	Ginger <i>Zingiber officinale</i>	Zingiberene Gingerols Paradol Shogaols Zingerone	Anti-hyperglycemic effect, Antioxidant activity, Anti-inflammatory effect, Analgesic activity, Cancer preventive ability [82-86]
5	Ginseng <i>Panax ginseng</i>	Ginsenosides Panaxosides	Anti-tumour activity [87-89], Anti-diabetic effect [24], Enhanced liver function, Stimulating immune and nervous system [87-89]
6	Garlic <i>Allium sativum</i>	Alliin Allicin	Anti-inflammatory effect, Antigout effect, Antithrombotic effect, Hypotensive activity, Antihyperlipidemic effect [90-92]
7	Onion <i>Allium cepa</i>	Allicin Alliin	Hypoglycemic activity [24, 93], Antiatherosclerosis effect [75]
8	Gingko/ maidenhair <i>Ginkgo biloba</i>	Ginkgolide Bilobalide	Antioxidant activity, Increasing peripheral blood flow [94- 95], Treatment of post-thrombotic syndrome [89]
9	Valerian <i>Valeriana officinalis</i>	Valerenic acid Valerate	Tranquillizer effect [24, 96]
10	Liquorice <i>Glycyrrhiza glabra</i>	Glabridin Glycyrrhizin Liquirtin	Anti-inflammatory effect, Expectorant, Antioxidant activity, Hepatoprotective effect, Anti-carcinogenic activity [97- 99]
11	Gotu kola <i>Centella asiatica</i>	Asiaticoside Madecassoside	Nervine tonic, Anti-anxiety effect, Anticancer activity [100]

**Table 1:** Herbal Materials and their Secondary Metabolites that Impart Nutraceutical Properties  
(Table 1 Continued)

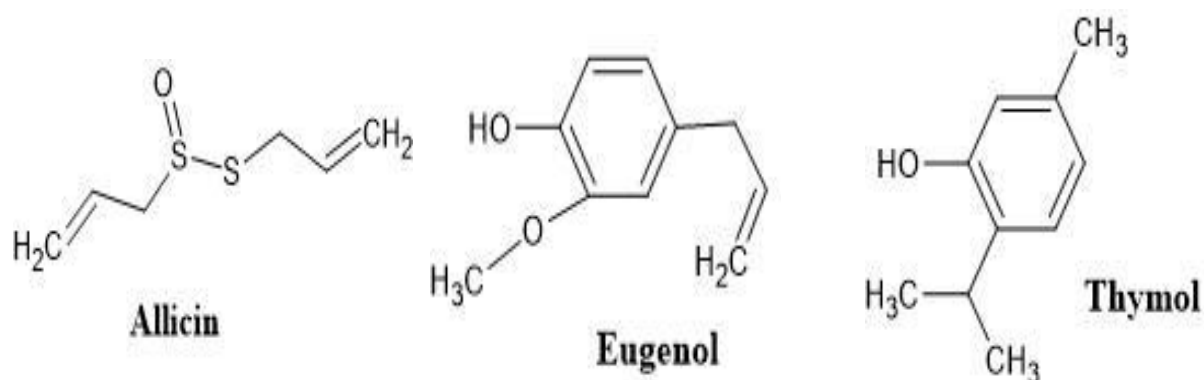
No	Potential Herb	Active Compounds	Supporting NCDs/ Beneficial Action
12	Purple coneflower <i>Echinacea purpurea</i>	Alkylamide Echinacoside	Anti-inflammatory effect [101], Immunomodulator [102]
13	White willow <i>Salix alba</i>	Salicin	Anti-inflammatory effect, Analgesic, Treatment of rheumatic and arthritis [103-105]
14	Goldenseal <i>Hydrastis canadensis</i>	Hydrastine Berberine and Canadine	Antihemorrhagic [104, 106]
15	Quinoa <i>Chenopodium quinoa</i>	Gallic acid and other polyphenols Saponinshas Flavonoids Lysine Amino acid Phytosterols Phytoecdysteroids	Antioxidant activity, Anti-obesity, Hypocholesterolemic, Managing malnutrition, Anti-hyperglycemic [107-109]
16	Lavender <i>Lavandula spica L.</i>	Tannins	Cure depression and hypertension [76] Support Asthma [42]
17	Parsley <i>Petroselinum crispum</i>	Apiol	Diuretic activity [76, 110]
18	Olive <i>Olea europaea</i>	Hydroxytyrosol, Oleuropein Tyrosol Oleuropein Aglycone	Antioxidant activity [111]
19	Rooibos <i>Aspalathus linearis</i>	Aspalathin and other polyphenols	Antioxidant activity, Hepatoprotective activity, Lipid-lowering effect Antidiabetic effect [112, 114]
20	Pumpkin <i>Cucurbita maxima</i>	Beta carotene	Antioxidant activity [115]
21	Guava <i>Psidium guajava</i>	Lycopene	Antioxidant activity [48, 116-118], Anticancer effect, Antihyperglycemic effect, Antihyperlipidemic effect [116-118]



**Table 1:** Herbal Materials and their Secondary Metabolites that Impart Nutraceutical Properties  
(Table 1 Continued)

No	Potential Herb	Active Compounds	Supporting NCDs/ Beneficial Action
22	Grapes <i>Vitis vinifera</i> L.	Resveratrol	Antioxidant activity, Antihypertensive effect [119]
23	Cinnamon <i>Cinnamomum verum</i>	Barely reported	Anti-diabetic effect [120]
24	Long Coriander <i>Eryngium foetidum</i>	Phenols, Flavonoids, Tannins, Polyphenols	Analgesic effect, Hypotensive effect, Anti-convulsant effect, Hepato-protective effect, Antioxidant activity [122, 123]

**Table 2:** Few Recognized Plant-Derived Active Compounds



**Source:** Garlic

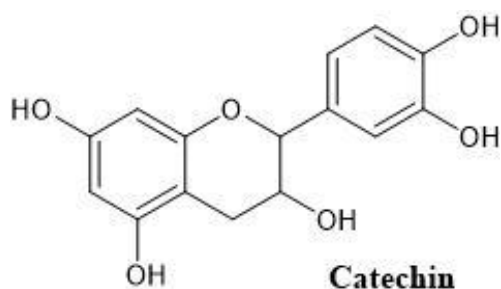
**Uses:** Protection against atherosclerosis, diabetes, high blood pressure, cholesterol

**Source:** Cinnamon, Clove

**Uses:** Antioxidant, gentle anaesthetic, and antiseptic activities

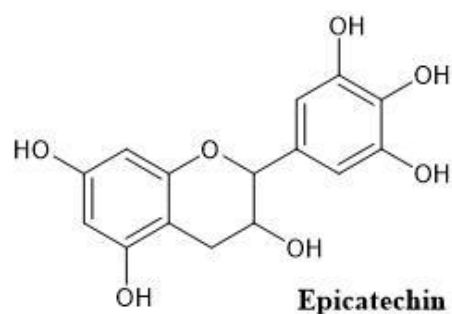
**Source:** Thyme

**Uses:** Helps in oral health, cancer-preventive, supports cardiovascular disease



**Source:** Tea and Pome Fruits

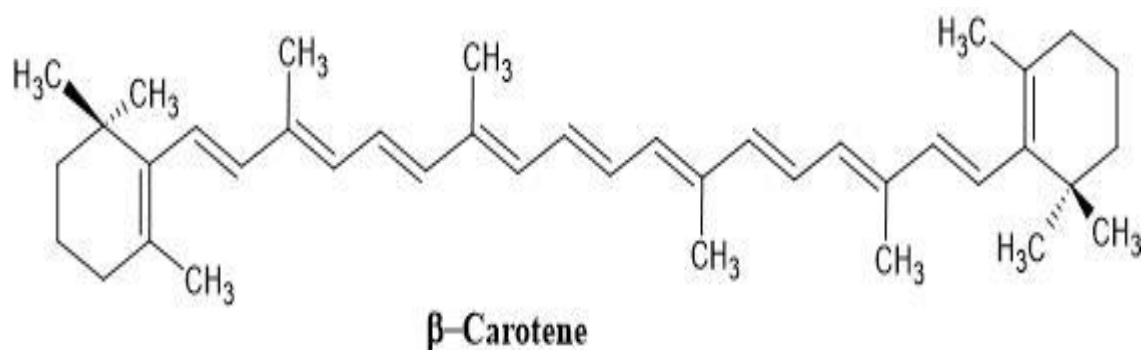
**Uses:** Antioxidant, Anticarcinogenic, Antidiabetic, Antiatherogenic



**Source:** Green tea, Dark Chocolate

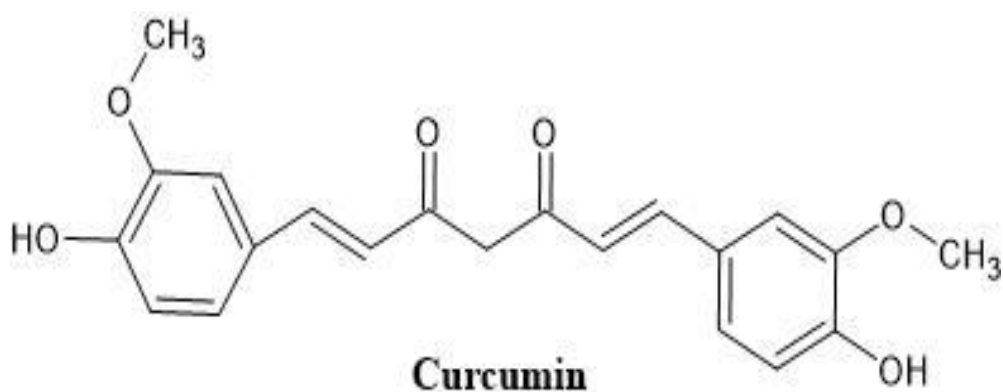
**Uses:** Antioxidant

**Table 2:** Few Recognized Plant-Derived Active Compounds  
(Table 2 Continued)



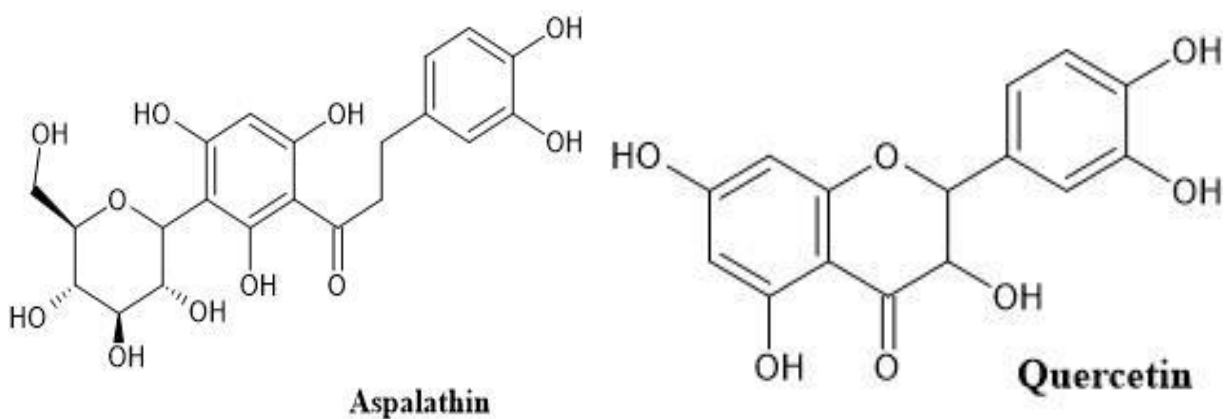
**Source:** Yellow – Red Fruits and Vegetables

**Uses:** Antioxidants, Protection against Cancer, Heart disease, Alzheimer's disease



**Source:** Turmeric

**Uses:** Antioxidant, Protection against heart disease, brain disease, cancer, arthritis, and depression



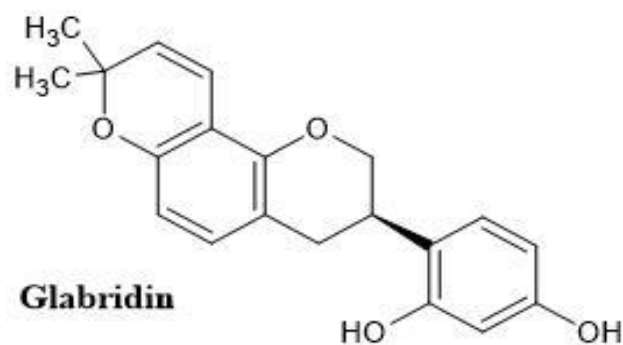
**Source:** Rooibos

**Uses:** Antioxidant, Antidiabetic

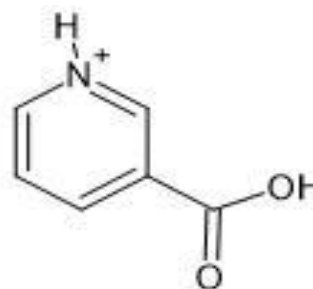
**Source:** Apples, Berries, Grapes, Onion

**Uses:** Antioxidant, reducing cancer risk, neuroprotective, preventing cardiovascular disease

**Table 2:** Few Recognized Plant-Derived Active Compounds  
(Table 2 Continued)



**Glabridin**



**Trigonellin**

**Source:** *Liquorice*

**Uses:** *Antioxidant, Hepatoprotective, Anticarcinogenic, Anti-inflammatory*

**Source:** *Fenugreek, Japanese Radish, Oats, Potatoes*

**Uses:** *Hypoglycemic, hypolipidemic, neuroprotective, antimigraine, sedative, memory-improving, antibacterial, antiviral, and anti-tumour*

countries show tidal growth in the nutraceutical market [41, 43, 130]. Although the existing market is smaller, China (6 billion US dollars per year), Brazil (1.9 billion US dollars in 2009), and Russia (75 million US dollars in 2004) also showcase a growing market for functional foods [130]. Most recent reports states that, at a compound annual growth rate (CAGR) of 5.7%, the worldwide functional food market is anticipated to increase from \$161.99 billion in 2020 to \$171.25 billion in 2021 [131]. Companies adopting the new normal condition after the covid - 19 impact has been influenced in this growth while it is expected to rise at 8% CAGR to reach \$228.79 billion in 2025 [131, 132].

### Product Development

With the rising demand for functional foods and nutraceuticals, product developments with commercial feasibility play a useful role, facilitating both medicinal and economic aspects. However, the production of functional foods or nutraceuticals has penetrated only a very small area of its potential capacity.

According to several definitions and categorizations, functional foods and nutraceuticals may also include prebiotics

and probiotics, enhanced products with omega fatty acids, functional meat products, algae or seaweed-based products, etc. [10, 13].

In this review article, the focus was given only to the plant/herbal-based product development of functional foods and nutraceuticals. However, even with the ample worldwide herbal profiles, there are only a few types of functional foods and/or nutraceuticals that have been reported in previous studies. Some examples are summarized in the below table (see Table 3) with their respective health-promoting activities.

As per the referenced products, the beverage production was the most outstanding. Moreover, bakery products, dairy products, confectionaries, tablets, capsules, and supplements with herbal incorporation were also considered in developing functional foods and nutraceuticals.

In addition to single herbal products, some researchers have focused on developing significantly impactful functional foods and nutraceuticals for specific chronic diseases with combinations of several plants and herbal materials. For example, Wijaya *et al.* [156] have developed a functional drink with

**Table 3:** Some Product Developments with Functional Food and/or Nutraceutical Properties from Previous Literature

No	Herbal Material	Plant Parts in Use	Food Type	Functional Interest	Reference
1	Rooibos <i>Aspalathus linearis</i>	Leaves	Tea Beverage	-	[133]
			Rooibos Tea	Antioxidant activity	[134]
				Antidiabetic activity	[127]
2	Quinoa <i>Chenopodium quinoa</i>	Grains	Flour, Biscuits, Pasta	Anti-diabetic properties	[135] [107]
3	Tea <i>Camelia sinensis</i>	Leaves	Green Tea	Reduce cholesterol, Raise energy, Stimulate mental power, Reducing the risk of coronary artery disease	[136] [137]
4	Java Tea (Cat whiskers) <i>Orthosiphon Stamineus</i>	Leaves	Java Tea	Antiallergenic effect, Antihypertensive activity, Anti-inflammatory effect, Diuretic properties	[136]
5	Roselle (Hibiscus) <i>Hibiscus sabdariffa</i>	Flowers	Functional Beverage		[138]
6	Lemon-Lime <i>Citrus limon, Citrus aurantiifolia</i>	Fruit	Frozen dessert	Nutritious supplement	[139]
7	Star fruit <i>Averrhoa carambola</i>	Fruit Juice	Functional beverage		[140]
8	Mushrooms <i>L. edodes</i>	Paste	Functional noodles	Antihypercholesterolemic activity	[141]
9	Pumpkin <i>Curcubita maxima</i>		Fermented functional beverage	Supports Diabetes	[142]
10	Licorice <i>Glycyrrhiza uralensis</i>	Extract	Herbal Lollipop	Reduce dental cavities	[143]
11	Ginger <i>Zingiber officinale</i>		Ginger honey candy		[144]

**Table 3:** Some Product Developments with Functional Food and/or Nutraceutical Properties from Previous Literature (*Table 3 Continued*)

No	Herbal Material	Plant Parts in Use	Food Type	Functional Interest	Reference
12	Mate <i>Ilex paraguariensis</i> A.St.-Hil	Leaf Extract	Fermented functional beverage	Antioxidant activity, hypocholesterolemic and hepatoprotective effect	[145]
13	Tulshi <i>Ocimum sanctum</i> Moringa <i>Moringa oleifera</i>	Leaves	Herbal Biscuits		[146]
14	Pomegranate <i>Punica granatum</i>	Encapsulated peel phenolic	Ice cream	Antioxidant activity and a- glucosidase inhibitory activities	[147]
15	Guava <i>Psidium guajava</i>		Guava Cheese (fruit snack)	Antioxidant activity	[148]
16	Moringa <i>Moringa oleifera</i>	Leaves	Herbal tea		[149]
17	Kachai Lemon <i>Citrus jambhiri</i>	fruits	Squash, salt pickle, sweet pickle, candied peel, candied fruit slices, jelly	Nutritious supplement	[150]
18	Guava <i>Psidium guajava</i>	Leaf	Noodle or bread	hyperlipidaemic measures and supports high blood sugar level syndrome	[151]
19	Coffee <i>Coffea arabica</i> L. Siberian ginseng <i>Eleutherococcus senticosus</i> organic oat <i>Avena sativa</i> organic Gotu kola <i>Centella asiatica</i> Sassafrass <i>Sassafras albidum</i>	Beans  Flower pollen Straw  Leaves  Leaves	Energy drink	Boosting energy	[152]

**Table 3:** Some Product Developments with Functional Food and/or Nutraceutical Properties from Previous Literature (*Table 3 Continued*)

No	Herbal Material	Plant Parts in Use	Food Type	Functional Interest	Reference
20	Rtanique fruit (a hybrid of tangerine and sweet orange) ( <i>Citrus sinensis</i> × <i>Citrus reticulata</i> )		Apple snack	Antiradical capacity	[153]
21	Kyoho ( <i>Vitis labruscana</i> )	Skins	Herbal tea	Antioxidant activity	[154]
22	Parsley ( <i>Petroselinum crispum</i> )		Pasta		[110]
23	Heartwood ( <i>Caesalpinia sappan</i> )	Wood	BRE* Nutraceutical	Antioxidant activity, Antibacterial effect, Anti-inflammatory effect	[155]
24	Cocoa ( <i>Theobroma cacao</i> )	Beans	Cocoa and Chocolate	Preventing Cardiovascular disease	[37]
25	Grapes ( <i>Vitis vinifera</i> )	Skins	Wine	Antioxidant activity, Antihypertensive effect	[119]

a combination of Cat's whiskers (*Orthosiphon aristatus*), ginger (*Zingiber officinale*), Roscoe Lily (*Roscoea purpurea*), lime (*Citrus aurantiifolia*), lemon (*Citrus limon*), kaffir lime (*Citrus hirtellifolia*), and Curcuma (*Curcuma xanthorrhiza*) with anti-hyperglycemic effects [156, 157]. Another functional beverage with cistus (*Cistus incanus*), green tea (*Camellia sinensis*), nettle leaves (*Urtica dioica*), artichoke (*Cynara scolymus*), Siberian ginseng (*Eleutherococcus senticosus*), ginger (*Zingiber officinale*), purple coneflower (*Echinacea purpurea*), Aloe (*Aloe vera* L.), horsetail (*Equisetum arvense*), lingonberry (*Vaccinium vitisidaea*), silver birch (*Betula pendula*), and chamomile (*Matricaria chamomilla*) was developed by Skąpska et al. [158] to yield higher antioxidant capacity [158].

Most of these studies are limited to the laboratory-level, and therefore, it is required to expand them to the commercial level. Further, there are many novel product

developments at the research/experimental level, and even in the established market that is not published on scientific platforms due to trade secrets, pending patents, unproven health claims, and many other reasons.

Given the assessed and identified increasing global demand for functional foods and nutraceuticals, it is clear that commercial production of the aforementioned products, as well as novel research on the same, would benefit the community by lowering the medical costs while earning more economic benefits.

#### Physiological Benefits of Functional Foods/Nutraceuticals

Among the physiological benefits to human health imparted by functional foods and nutraceuticals, a wealth of literature provides evidence on preventing or treating non-communicable diseases with functional food or nutraceutical applications [115, 126].

Type 2 diabetes, or hyperglycaemia, is a predominant health concern that has a potential for prevention and management with the use of functional foods and/or nutraceuticals and their bioactive compounds [59]. Diets with high phytochemical content, high antioxidant capacity, and polyphenolic content act on lowering the risk of diabetes and predisposing factors [59, 159]. Another finding, which defines functional foods or nutraceuticals as individual bioactive chemicals or foods claimed to have health-promoting properties, provides several such applications in managing and preventing type 2 diabetes [160]. Predominant herbal applications, namely, American ginseng, Chinese herbs, Fenugreek, and Nopal, are some of the given examples in this context.

Nutraceutical compounds such as resveratrol from grape wine, curcumin from turmeric, cocoa, quercetin, brassica, and berberine were found to be beneficial in the prevention of cardiovascular diseases and their associated health conditions, hypertension, atherosclerosis, heart failure, and diabetes [119].

Many nutraceuticals are in action towards the treatment of cancers [64, 126]. Among these dietary supplements (Eg- *Punicagranum*, *Triticumaestivum*, *Beta vulgaris*), plant secondary metabolites (Eg- flavonoids, phenols, carotenoids, alkaloids, saponins, tannins, steroids) and medicinal herbs (Eg- *Cynara cardunculus*, *Azadirachta indica*, *Santalum album*) play a significant role in colon cancers [126]. Ginger is one of the major potential ingredients in the form of water extract, paste, or dried powder in many functional food products proven to inhibit the progression of prostate tumors [161].

### CONCLUSIONS

This review summarizes the recognition of functional foods and nutraceuticals as potential natural remedies for mitigating the global health risk of NCDs. According to recent research findings, the important pharmacological properties such as

antioxidant, anti-inflammatory, anticancer, anti-hyperglycaemic, anti-lipidemic, and so on exerted by plant secondary metabolites, prospective and developed functional foods and nutraceuticals of herbal origin are narrated. The review concludes that developing easily adoptable technologies for producing functional foods and nutraceuticals would support the community in adopting healthier dietary patterns and promoting such plants as economical crops would thereby obtain both medicinal and economic gains for modern society

### FUNDING SOURCES

World Bank-funded Sri Lankan government operation to support the higher education sector; Accelerating Higher Education Expansion and Development (AHEAD) project. [AHEAD/RUH/DOR/05].

### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

### AUTHORS' CONTRIBUTIONS

UB: Conceptualized the study and wrote the manuscript. NL and VPB: Reviewed the manuscript. All authors read and approved the manuscript.

### REFERENCES

1. Habib SH, Saha S. Burden of non-communicable disease: Global overview. *Diabetes Metab Syndr Clin Res Rev*. 2010; 4(1):41-7.
2. World Health Organization (WHO). Noncommunicable diseases Progress Monitor. 2020.
3. Hunter DJ, Reddy KS. Noncommunicable diseases. *N Engl J Med*. 2013; 369(14):1336-43.
4. World Health Organization (WHO). High-level meeting of the UN general assembly to undertake the comprehensive review and assessment of the 2011 political declaration on NCDs [Internet]. Noncommunicable diseases and Mental health. 2014 [cited 2021 May 3]. Available from: <https://www.who.int/nmh/>

- events/2014/high-level-unga/en/
5. Bennett JE, Stevens GA, Mathers CD, Bonita R, Rehm J, Kruk ME, et al. NCD Countdown 2030: Worldwide trends in non-communicable disease mortality and progress towards Sustainable Development Goal target 3.4. *Lancet*. 2018; 392(10152):1072–88.
  6. World Health Organization (WHO). Noncommunicable-Diseases [Internet]. 2019. Available from: <http://www.who.int/news-room/fact-sheets/detail/noncommunicablediseases>
  7. Miranda S, Marques A. Pilates in noncommunicable diseases: A systematic review of its effects [Internet]. Vol. 39, *Complementary Therapies in Medicine*. Elsevier Ltd; 2018. 114–130 p.
  8. World Health Organization (WHO). Noncommunicable Diseases: Risk Factors [Internet]. The Global Health Observatory. 2021 [cited 2021 May 3].
  9. Peters R, Ee N, Peters J, Beckett N, Booth A, Rockwood K, et al. Common risk factors for major non-communicable disease, a systematic overview of reviews and commentary: The implied potential for targeted risk reduction. *Ther Adv Chronic Dis*. 2019; 10:1–14.
  10. Jones PJ. Functional foods - More than just nutrition. *Clinical nutrition. Canadian Medical Association Journal*. 2002; 166.
  11. Doyon M, Labrecque JA. Functional foods: A conceptual definition. *Br Food J*. 2008; 110(11):1133–49.
  12. Pandey M, Verma RK, Saraf SA. Nutraceuticals: New era of medicine and health. *Asian J Pharm Clin Res*. 2010; 3(1):11–5.
  13. Siro I, Kapolna E, Kapolna B, Lugasi A. Functional food. Product development, marketing and consumer acceptance: A review. *Appetite*. 2008; 51:456–67.
  14. Ali A, Rahut DB. Healthy foods as proxy for functional foods: Consumers' awareness, perception, and demand for natural functional foods in Pakistan. *Hindawi Int J Food Sci*. 2019; 2019:1–12.
  15. Menrad, K. K. Market and marketing of functional food in Europe. *J Food Eng*. 2003; 56(Nr.2-3):181–8.
  16. Kalra EK. Nutraceutical: Definition and introduction. *AAPS PharmSci*. 2003; 5(3):1–2.
  17. Andlauer W, Fürst P. Nutraceuticals: A piece of history, present status and outlook. *Food Res Int*. 2002; 35(2–3):171–6.
  18. Prabu SL, Suriyaprakash TNK, Kumar CD, Sureshkumar S, Ragavendran T. Nutraceuticals: A review. *Elixir Pharm*. 2012; 46:8372–7.
  19. Shahidi F. Nutraceuticals and functional foods: Whole versus processed foods. *Trends Food Sci Technol*. 2009; 20(9):376–87.
  20. Gul K, Singh AK, Jabeen R. Nutraceuticals and functional foods: the foods for the future world. *Crit Rev Food Sci Nutr*. 2016; 56(16):2617–27.
  21. Zeisel SH. Regulation of “nutraceuticals.” *Sci Compass*. 1999; 285:1853–5.
  22. Shahidi F. Functional foods: Their role in health promotion and disease prevention. *J Food Sci*. 2004; 69(5):146–9.
  23. Murthy M. Nutraceuticals, functional foods and medical foods: Commentary and caveats. *J Nutraceuticals, Funct Med Foods*. 1998; 1(3):73–99.
  24. Chauhan B, Kumar G, Kalam N, Ansari SH. Current concepts and prospects of herbal nutraceutical: A review. *J Adv Pharm Technol Res*. 2013; 4(1):4–8.
  25. Roberfroid MB. Global view on functional foods: European perspectives. *Br J Nutr*. 2002; 88(S2): S133–8.
  26. Vicentini A, Liberatore L, Mastrocola D. Functional foods: Trends and development. *Ital J Food Sci*. 2016; 28:338–52.
  27. Arai S. Global view on functional foods: Asian perspectives. *Br J Nutr*. 2002; 88(S2): S139–43.
  28. Stein AJ, Rodriguez-Cerezo E. Functional foods in the European Union. *JRC Scientific and Technical Reports*. 2008.
  29. El Sohaimy SA. Functional foods and nutraceuticals-modern approach to food science. *World Appl Sci J*. 2012; 20(5):691–708.
  30. Smith J, Charter E. *Functional Food Product*



- Development*. Smith J, Charter E, editors. Charlottetown, Canada: Wiley-Blackwell; 2010. 1–536 p.
33. Madhujith T, Wedamulla N. Functional foods and health. In: Premalal R, Gamini DS, Pahan P, Jeevika P, editors. *Agricultural Research for Sustainable Food Systems in Sri Lanka*. 1<sup>st</sup> ed. Springer Nature Singapore Pte Ltd; 2020. p. 301–31.
  34. Balsano C, Alisi A. Antioxidant effects of natural bioactive compounds. *Curr Pharm Des*. 2009; 15:3063–73.
  35. Pan M-H, Ghai G, Ho C-T. Food bioactives, apoptosis, and cancer. *Mol Nutr Food Res*. 2008; 52(1):43–52.
  36. Sarkar FH. Nutraceuticals and cancer. *Nutraceuticals and Cancer*. 2013:1–379.
  37. Hasler CM, Kundrat S, Wool D. Functional foods and cardiovascular disease. *Curr Atheroscler Rep*. 2000; 2:467–75.
  38. Zuchi C, Ambrosio G, Lüscher TF, Landmesser U. Nutraceuticals in cardiovascular prevention: Lessons from studies on endothelial function. *Cardiovasc Ther*. 2010; 28(4):187–201.
  39. Sosnowska B, Penson P, Banach M. The role of nutraceuticals in the prevention of cardiovascular disease. *Cardiovasc Diagn Ther*. 2017; 7(Suppl 1): S21–31.
  40. Alkhatib A, Tsang C, Tiss A, Bahorun T, Arefanian H, Barake R, et al. Functional foods and lifestyle approaches for diabetes prevention and management. *Nutrients*. 2017; 9(12):1–18.
  41. Venkatakrishnan K, Chiu HF, Wang CK. Popular functional foods and herbs for the management of type-2-diabetes mellitus: A comprehensive review with special reference to clinical trials and its proposed mechanism. *J Funct Foods*. 2019; 57:425–38.
  42. Davì G, Santilli F, Patrono C. Nutraceuticals in diabetes and metabolic syndrome. *Cardiovasc Ther*. 2010; 28(4):216–26.
  43. Das L, Bhaumik E, Raychaudhuri U, Chakraborty R. Role of nutraceuticals in human health. *J Food Sci Technol*. 2012; 49(2):173–83.
  44. Chintale AG, Kadam VS, Sakhare RS, Birajdar GO, Nalwad DN. Role of nutraceuticals in various diseases: A comprehensive review. *Int J Res Pharm Chem*. 2013; 3(2):290–9.
  45. Shinde N, Bangar B, Deshmukh S, Kumbhar P. Nutraceuticals: A review on current status. *Res J Pharm Technol*. 2014; 7(1):110–3.
  46. Joshi V. Phyto-nutrients, nutraceutical, fermented foods and traditional medicine in human health: Issues, concerns and strategies. *Nov Tech Nutr Food Sci*. 2018; 1(3):1–9.
  47. World Health Organization (WHO). World Health Organization Traditional Medicine Strategy 2014-2023. 2013. WHO. Available from: [http://apps.who.int/iris/bitstream/10665/92455/1/9789241506090\\_eng.pdf?ua=1](http://apps.who.int/iris/bitstream/10665/92455/1/9789241506090_eng.pdf?ua=1) (Accessed 09.09.2016)
  48. Velioglu SY, Ekici L, Poyrazoglu ES. Phenolic composition of European cranberrybush (*Viburnum opulus* L.) berries and astringency removal of its commercial juice. *Int J Food Sci Technol*. 2006; 41:1011–5.
  49. Nirmal NP, Panichayupakaranant P. Anti-propionibacterium acnes assay-guided purification of brazilin and preparation of brazilin-rich extract from *Caesalpinia sappan* heartwood. *Pharm Biol*. 2014; 52(9):1204–7.
  50. Zhu X, Ouyang W, Lan Y, Xiao H, Tang L, Liu G, et al. Anti-hyperglycemic and liver-protective effects of flavonoids from *Psidium guajava* L. (guava) leaf in diabetic mice. *Food Biosci*. 2020; 35 (March):100574.
  51. Shikha R, Pawan J, Manju K. Review Article on Tisanes: Recreational use of local plants. *Int J Sci Adv Res Technol*. 2019; 5(2):14–9.
  52. Liyanagamage DSNK, Jayasinghe S, Attanayake AP, Karunaratne V. Acute and subchronic toxicity profile of a polyherbal drug used in Sri Lankan traditional medicine. *Hindawi Evidence-based Complement Altern Med*. 2020; 2020:1–12.

53. Pandey KB, Rizvi SI. Plant polyphenols as dietary antioxidants in human health and disease. *Oxid Med Cell Longev*. 2009; 2(5):270–8.
54. Pietta P, Minoggio M, Bramati L. Plant polyphenols: Structure, occurrence and bioactivity. *Stud Nat Prod Chem*. 2003; 28:257–312.
55. Graf BA, Milbury PE, Blumberg JB. Flavonols, flavones, flavanones, and human health: Epidemiological evidence. *J Med Food*. 2005;8(3):281–90.
56. Arts ICW, Hollman PCH. Polyphenols and disease risk in epidemiologic studies. *Am J Clin Nutr*. 2005; 81(1 Suppl).
57. Nardini M, Natella F, Scaccini C. Role of dietary polyphenols in platelet aggregation. A review of the supplementation studies. *Platelets*. 2007; 18(3):224–43.
58. Dubick MA, Omaye ST. Evidence for grape, wine and tea polyphenols as modulators of atherosclerosis and ischemic heart disease in humans. *J Nutraceuticals, Funct Med Foods*. 2001; 3(3):67–93.
59. Vita JA. Polyphenols and cardiovascular disease: Effects on endothelial and platelet function. *Am J Clin Nutr*. 2005; 81(1 Suppl):292–7.
60. Yang CS, Landau JM, Huang M, Newmark HL. Inhibition of carcinogenesis by dietary polyphenolic compounds. *Annu Rev Nutr*. 2001; 21:381–406.
61. Bahadoran Z, Mirmiran P, Azizi F. Dietary polyphenols as potential nutraceuticals in management of diabetes: A review. *J Diabetes Metab Disord*. 2013; 12(1):1–9.
62. Letenneur L, Proust-Lima C, Le Gouge A, Dartigues JF, Barberger-Gateau P. Flavonoid intake and cognitive decline over a 10-year period. *Am J Epidemiol*. 2007; 165(12):1364–71.
63. Singh M, Arseneault M, Sanderson T, Murthy V, Ramassamy C. Challenges for research on polyphenols from foods in Alzheimer's disease: Bioavailability, metabolism, and cellular and molecular mechanisms. *J Agric Food Chem*. 2008 Jul; 56(13):4855–73.
64. Dai Q, Borenstein AR, Wu Y, Jackson JC, Larson EB. Fruit and Vegetable juices and Alzheimer's Disease: The kame project. *Am J Med*. 2006; 119(9):751–9.
65. Scarmeas N, Luchsinger JA, Mayeux R, Stern Y. Mediterranean diet and Alzheimer disease mortality. *Neurology*. 2007; 69(11):1084–93.
66. Prakash, D., Gupta, C., Sharma G. Importance of phytochemicals in nutraceuticals. *J Chinese Med Res Dev*. 2012; 1(3):70–8.
67. Prakash D, Kumar N. Cost effective natural antioxidants. In: Gerald JK, Watson RR, Preedy VR, editors. *Nutrients, Dietary Supplements, and Nutraceuticals: Cost Analysis Versus Clinical Benefits*. Totowa, NJ: Humana Press; 2011. p. 163–87.
68. Sakamoto T, Horiguchi H, Oguma E, Kayama F. Effects of diverse dietary phytoestrogens on cell growth, cell cycle and apoptosis in estrogen-receptor-positive breast cancer cells. *J Nutr Biochem*. 2010; 21(9):856–64.
69. Prakash D, Gupta C. Role of phytoestrogens as nutraceuticals in human health: A review. *Bio Technol An Indian J*. 2011; 5(3):171–8.
70. Prof D, Dhakarey R, Misra A. Carotenoids: The phytochemicals of nutraceutical importance. *Indian J Agric Biochem*. 2004; 17:1–8.
71. Stahl W, Sies H. Bioactivity and protective effects of natural carotenoids. *Biochim Biophys Acta Mol Basis Dis*. 2005; 1740(2):101–7.
72. Dillard CJ, Bruce German J. Phytochemicals: Nutraceuticals and human health. *J Sci Food Agric*. 2000; 80(12):1744–56.
73. Lovegrove A, Edwards CH, De Noni I, Patel H, El SN, Grassby T, et al. Role of polysaccharides in food, digestion, and health. *Crit Rev Food Sci Nutr*. 2015; 1–67.
74. Saleem R, Faizi S, Siddiqui BS, Ahmed M, Hussain SA, Qazi A, et al. Hypotensive effect of chemical constituents from *Aloe*

- barbadensis*. *Planta Med.* 2001; 67(8):757–60.
77. Sánchez M, González-Burgos E, Iglesias I, Gómez-Serranillos MP. Pharmacological update properties of aloe vera and its major active constituents. *Molecules.* 2020; 25(6):1–37.
78. López A, De Tangil MS, Vega-Orellana O, Ramírez AS, Rico M. Phenolic constituents, antioxidant and preliminary antimycoplasmic activities of leaf skin and flowers of *Aloe vera* (L.) Burm. f. (syn. *A. barbadensis* Mill.) from the Canary Islands (Spain). *Molecules.* 2013; 18(5):4942–54.
79. Sharma R, Amin H, Prajapati P. Plant kingdom nutraceuticals for diabetes. *J Ayurvedic Herb Med.* 2016; 2(6):224–8.
80. Ghani U, Naeem M, Rafeeq H, Imtiaz U, Amjad A, Ullah S, et al. A novel approach towards nutraceuticals and biomedical applications. *Sch Int J Biochem.* 2019; 02(10):245–52.
81. Singh J, Rahul AK, Khinchi M., Nitin N, Singh S. A review on food supplement - Nutraceuticals. *Asian J Pharm Res Dev.* 2017; 5(3):1–7.
82. Butterweck V, Schmidt M. St. John's wort: Role of active compounds for its mechanism of action and efficacy. *Wiener Medizinische Wochenschrift.* 2007; 157(13–14):356–61.
83. Patočka J. The chemistry, pharmacology, and toxicology of the biologically active constituents of the herb *Hypericum perforatum* L. *J Appl Biomed.* 2003; 1:61–70.
84. Li S. Chemical composition and product quality control of turmeric (*Curcuma longa* L.). *Pharm Crop.* 2011; 5(1):28–54.
85. Roth GN, Chandra A, Nair MG. Novel bioactivities of *Curcuma longa* constituents. *J Nat Prod.* 1998; 61(4):542–5.
86. Ali BH, Blunden G, Tanira MO, Nemmar A. Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale Roscoe*): A review of recent research. *Food Chem Toxicol.* 2008; 46(2):409–20.
87. Mao QQ, Xu XY, Cao SY, Gan RY, Corke H, Beta T, et al. Bioactive compounds and bioactivities of ginger (*zingiber officinale roscoe*). *Foods.* 2019; 8(6):1–21.
88. Malhotra S, Singh AP. Medicinal Properties of Ginger (*Zingiber officinale roscoe*). *Nat Prod Radiance.* 2003; 2(6):296–301.
89. Shukla Y, Singh M. Cancer preventive properties of ginger: A brief review. *Food Chem Toxicol.* 2007; 45(5):683–90.
90. Shahrajabian MH, Sun W, Cheng Q. Clinical aspects and health benefits of ginger (*Zingiber officinale*) in both traditional Chinese medicine and modern industry. *Acta Agric Scand Sect B Soil Plant Sci.* 2019; 69(6):546–56.
91. Yun TK, Lee YS, Lee YH, Kim SI, Yun HY. Anticarcinogenic effect of *Panax ginseng* C.A. Meyer and identification of active compounds. *J Korean Med Sci.* 2001; 16 Suppl(100):6–18.
92. Choi KT. Botanical characteristics, pharmacological effects and medicinal components of Korean *Panax ginseng* C A Meyer. *Acta Pharmacol Sin.* 2008; 29(9):1109–18.
93. Baldi A, Choudhary N, Kumar S. Nutraceuticals as therapeutic agents for holistic treatment of diabetes. *Int J Green Pharm.* 2013; 7(4):278–87.
94. Szychowski KA, Rybczyńska-Tkaczyk K, Gaweł-Bęben K, Aświeca M, Kara M, Jakubczyk A, et al. Characterization of active compounds of different Garlic (*Allium sativum* L.) Cultivars. *Polish J Food Nutr Sci.* 2018; 68(1):73–81.
95. Londhe VP, Gavasane AT, Nipate SS, Bandawane DD, Chaudhari PD. Role of Garlic (*Allium sativum*) in various diseases: An overview. *J Pharm Res Opin.* 2011; 1(4):129–34.
96. Tesfaye A, Mengesha W. Traditional uses, phytochemistry and pharmacological properties of Garlic (*Allium Sativum*) and its biological active compounds. *Int J Sci Res Sci Eng Technol.* 2015; 5(5):142–8.
97. Bora KS, Sharma A. Phytoconstituents and therapeutic potential of allium cepa linn: A Review. *Pharmacogn Rev.* 2009; 3(5):170–80.

98. Ding S, Dudley E, Plummer S, Tang J, Newton RP, Brenton AG. Quantitative determination of major active components in *Ginkgo biloba* dietary supplements by liquid chromatography/mass spectrometry. Rapid Commun Mass Spectrom. 2006; 20:2753–60.
99. Ude C, Schubert-Zsilavec M, Wurglics M. *Ginkgo biloba* extracts: A review of the pharmacokinetics of the active ingredients. Clin Pharmacokinet. 2013; 52(9):727–49.
100. Nandhini S, Narayanan KB, Ilango K. *Valeriana officinalis*: A review of its traditional uses, phytochemistry and pharmacology. Asian J Pharm Clin Res. 2018; 11(1):36–41.
101. Nitalikar MM, Munde KC, Dhore B V., Shikalgar SN. Studies of antibacterial activities of *Glycyrrhiza glabra* root extract. Int J PharmTech Res. 2010; 2(1):899–901.
102. Gupta VK, Fatima A, Faridi U, Negi AS, Shanker K, Kumar JK, et al. Antimicrobial potential of *Glycyrrhiza glabra* roots. J Ethnopharmacol. 2008; 116(2):377–80.
103. Pastorino G, Cornara L, Soares S, Rodrigues F, Oliveira MBPP. Liquorice (*Glycyrrhiza glabra*): A phytochemical and pharmacological review. Phyther Res. 2018; 32(12):2323–39.
104. Zainol MK, Abd-Hamid A, Yusof S, Muse R. Antioxidative activity and total phenolic compounds of leaf, root and petiole of four accessions of *Centella asiatica* (L.) Urban. Food Chem. 2003; 81(4):575–81.
105. Vimalanathan S, Kang L, Amiguet VT, Livesey J, Arnason JT, Hudson J. *Echinacea purpurea* aerial parts contain multiple antiviral compounds. Pharm Biol. 2005; 43(9):740–5.
106. Rajasekaran A, Sivagnanam G, Xavier R. Nutraceuticals as therapeutic agents: A review. Res J Pharm Tech. 2008; 1(4):328–40.
107. Piątczak E, Dybowska M, Płuciennik E, Kośła K, Kolniak-ostek J, Kalinowska-lis U. Identification and accumulation of phenolic compounds in the leaves and bark of *Salix alba* (L.) and their biological potential. Biomolecules. 2020; 10(10):1–17.
108. Egbuna C, Dable-Tupas G, editors. *Functional Foods and Nutraceuticals Bioactive Components, Formulations and Innovations*. Switzerland: Springer; 2020. 1–643 p.
109. Shara M, Stohs SJ. Efficacy and safety of White Willow bark (*Salix alba*) extracts. Phyther Res. 2015; 29(8):1112–6.
110. Scazzocchio F, Cometa MF, Tomassini L, Palmery M. Antibacterial activity of *Hydrastis canadensis* extract and its major isolated alkaloids. Planta Med. 2001; 67(6):561–4.
111. Arneja I, Tanwar B, Chauhan A. Nutritional composition and health benefits of golden grain of 21<sup>st</sup> century, quinoa (*Chenopodium quinoa* willd.): A review. Pakistan J Nutr. 2015; 14(12):1034–40.
112. Navruz-Varli S, Sanlier N. Nutritional and health benefits of quinoa (*Chenopodium quinoa* Willd.). J Cereal Sci. 2016; 69(May):371–6.
113. Laus MN, Gagliardi A, Soccio M, Flagella Z, Pastore D. antioxidant activity of free and bound compounds in Quinoa (*Chenopodium quinoa* Wild.) seeds in comparison with Durum wheat and emmer. J Food Sci. 2012; 77(11).
114. Sęczyk Ł, Świeca M, Gawlik-Dziki U, Luty M, Czyz J. Effect of fortification with parsley (*Petroselinum crispum* Mill.) leaves on the nutraceutical and nutritional quality of wheat pasta. Food Chem. 2016; 190:419–28.
115. AL-Asmari KM, Al-Attar AM, Abu-Zeid IM. Potent health benefits and components of olive oil: An overview. Biosci Res. 2020; 17(4):2673–87.
116. Millar DA, Bowles S, Windvogel SL, Louw J, Muller CJF. Effect of Rooibos (*Aspalathus linearis*) extract on atorvastatin-induced toxicity in C3A liver cells. J Cell Physiol. 2020; 235(12):9487–96.
117. Ajuwon OR aza., Oguntibeju OO moniy., Marnewick JL ucast. Amelioration of lipopolysaccharide-induced liver injury by aqueous rooibos (*Aspalathus linearis*)

- extract via inhibition of pro-inflammatory cytokines and oxidative stress. *BMC Complement Altern Med.* 2014; 14:392.
118. Mazibuko-Mbeje SE, Dlodla P V., Roux C, Johnson R, Ghoor S, Joubert E, et al. Aspalathin-enriched green rooibos extract reduces hepatic insulin resistance by modulating PI3K/AKT and AMPK pathways. *Int J Mol Sci.* 2019; 20(3):1-16.
  119. Jain N, Ramwat K. Nutraceuticals and antioxidants in prevention of diseases. In: *Natural Products*. Springer; 2013. p. 2560-77.
  120. Deguchi Y, Miyazaki K. Anti-hyperglycemic and anti-hyperlipidemic effects of guava leaf extract. *Nutr Metab.* 2010; 7(9):1-10.
  121. Wang H, Du YJ, Song HC.  $\alpha$ -Glucosidase and  $\alpha$ -amylase inhibitory activities of guava leaves. *Food Chem.* 2010;123(1):6-13.
  122. Luo Y, Peng B, Wei W, Tian X, Wu Z. Antioxidant and anti-diabetic activities of polysaccharides from guava leaves. *Molecules.* 2019; 24(1343):1-14.
  123. Carrizzo A, Izzo C, Forte M, Sommella E, Pietro P Di, Venturini E, et al. A novel promising frontier for human health: The beneficial effects of nutraceuticals in cardiovascular diseases. *Int J Mol Sci.* 2020; 21(22):1-40.
  124. Ranasinghe P, Galappaththy P, Constantine GR, Jayawardena R, Weeratunga HD, Premakumara S, et al. *Cinnamomum zeylanicum* (Ceylon cinnamon) as a potential pharmaceutical agent for type-2 diabetes mellitus: Study protocol for a randomized controlled trial. *BioMed Cent Trials.* 2017; 18(446):1-8.
  125. Costello RB, Dwyer JT, Saldanha L, Bailey RL, Merkel J, Wambogo E. Do cinnamon supplements have a role in glycemic control in type 2 diabetes - A narrative review. *J Acad Nutr Diet.* 2016; 116(11):1794-802.
  126. Shavandi MA, Haddadian Z, Ismail MHS. *Eryngium foetidum* L. *Coriandrum sativum* and *Persicaria odorata* L.: A Review. *J Asian Sci Res [Internet].* 2012; 2(8):410-26.
  127. Malik T, Pandey DK, Roy P, Okram A. Evaluation of phytochemicals, antioxidant, antibacterial and antidiabetic potential of *Alpinia galanga* and *Eryngium foetidum* plants of Manipur (India). *Pharmacogn J.* 2016; 8(5):459-64.
  128. Alissa EM, Ferns GA. Functional foods and nutraceuticals in the primary prevention of cardiovascular diseases. *J Nutr Metab.* 2012; 2012.
  129. Perera PK, Li Y. Functional herbal food ingredients used in type 2 diabetes mellitus. *Pharmacogn Rev.* 2012; 6(11):37-45.
  130. Kuppusamy P, Yusoff MM, Maniam GP, Ichwan SJA, Soundharrajan I, Govindan N. Nutraceuticals as potential therapeutic agents for colon cancer: A review. *Acta Pharm Sin B.* 2014; 4(3):173-81.
  131. Muller CJF, Joubert E, De Beer D, Sanderson M, Malherbe CJ, Fey SJ, et al. Acute assessment of an aspalathin-enriched green rooibos (*Aspalathus linearis*) extract with hypoglycemic potential. *Phytomedicine.* 2012; 20(1):32-9.
  132. Taylor P, Balentine DA, Wiseman SA, Bouwens LCM. Critical reviews in food science and nutrition: The chemistry of tea flavonoids. 2009; (March 2012):37-41.
  133. Salehi B, Mishra AP, Shukla I, Sharifi-Rad M, Contreras M del M, Segura-Carretero A, et al. Thymol, thyme, and other plant sources: Health and potential uses. *Phyther Res.* 2018; 32(9):1688-706.
  134. Williams M, Pehu E, Ragasa C. *Opportunities and challenges for developing functional foods*. Agriculture and Rural Development. Washington; 2006.
  135. Functional Foods Global Market Report 2021. The Business Research Company; 2021.
  136. Grand View Research. Functional Foods Market Worth \$275.7 Billion By 2025. Grand View Research; 2019. Available from: <https://www.grandviewresearch.com/press-release/global-functional-foods-market> [Accessed on 04th July 2022].
  137. Joubert E, de Beer D. Rooibos (*Aspalathus linearis*) beyond the farm gate: From

- herbal tea to potential phytopharmaceutical. South African J Bot [Internet]. 2011;77(4):869–86.
138. Shimamura N, Miyase T, Umehara K, Warashina, Fujii S. Phytoestrogens from *Aspalathus linearis*. Biol Pharm Bull. 2006; 29(6):1271–4.
139. Graf BL, Rojas-silva P, Rojo LE, Delatorre-herrera J, Balde ME, Raskin I. Innovations in health value and functional food development of Quinoa (*Chenopodium quinoa* Willd.). Compr Rev food Sci food Saf. 2015; 14:431–45.
140. Maheswari C, Venkatnarayanan R, Babu P, Kandasamy CS. Green tea (Cardiac tea) vs Java tea (kidney tea): A Review. Res J Pharm Technol. 2015; 8(1):94–100.
141. Hirano R, Momiyama Y, Takahashi R, Taniguchi H, Kondo K, Nakamura H, et al. Comparison of green tea intake in Japanese patients with and without angiographic coronary artery disease. Am J Cardiol. 2002; 90(10):1150–3.
142. Ogundele OMA, Awolu OO, Badejo AA, Nwachukwu ID, Fagbemi TN. Development of functional beverages from blends of *Hibiscus sabdariffa* extract and selected fruit juices for optimal antioxidant properties. Food Sci Nutr. 2016; 4(5):679–85.
143. Koss R, Koss A. Nutritional frozen dessert and methods of manufacture. Vol. 2. United States: United states patents; US 7,033,629 B2, 2006.
144. Lu Y, Tan CW, Chen D, Liu SQ. Potential of three probiotic lactobacilli in transforming star fruit juice into functional beverages. Wiley Food Sci Nutr. 2018; 6(8):2141–50.
145. Reis FS, Martins A, Vasconcelos MH, Morales P, Ferreira ICFR. Functional foods based on extracts or compounds derived from mushrooms. Trends Food Sci Technol. 2017; 66:48–62.
146. Koh WY, Uthumporn U, Rosma A, Yuen KH. Fermented pumpkin-based beverage inhibits key enzymes of carbohydrate digesting and extenuates postprandial hyperglycaemia in type-2 diabetic rats. Acta Aliment. 2018; 47(4):495–503.
147. Hu C, He J, Eckert R, Wu X, Li L, Tian Y. Development and evaluation of a safe and effective sugar free herbal lollipop that kills cavity causing bacteria. Int J Oral Sci. 2011; 3(1):13–20.
148. Gupta R, Singh B, Shivhare US. Optimization of osmo-convective dehydration process for the development of honey-ginger candy using response surface methodology. Dry Technol an Int J. 2012; 30(7):750–9.
149. Lima IFP, Lindner JDD, Soccol VT, Parada JL, Soccol CR. Development of an innovative nutraceutical fermented beverage from herbal mate (*Ilex paraguariensis* A. St. -Hil.) Extract. Int J Mol Sci. 2012; 13:788–800.
150. Alam A, Alam J, Hakim A, Huq AKO, Moktadir SMG. Development of fiber enriched herbal biscuits: A preliminary Study on Development of fiber enriched herbal biscuits: A preliminary study on sensory evaluation and chemical composition. Int J Nutr Food Sci. 2014; 3(4):246–50.
151. Cam M, Icyer CN, Erdogan F. Pomegranate peel phenolics: microencapsulation, storage stability and potential ingredient for functional food development. Food Sci Technol. 2013; 1–7.
152. Patel P, Ellis K, Sunkara R, Shackelford L, Ogutu S, T. Walker L, et al. Development of a functional food product using guavas. Food Nutr Sci. 2016; 07:927–37.
153. Wickramasinghe YWH, Wickramasinghe I, Wijesekara I. Effect of steam blanching, dehydration temperature & time, on the sensory and nutritional properties of a herbal tea developed from *Moringa oleifera* leaves. Int J Food Sci. 2020; 2020:1–11.
154. Kuna A, Sowmya M, Sahoo M. R, Mayengbam PD, Dasgupta M, Sreedhar M. Value addition and sensory evaluation of products made from underutilized Kachai Lemon (*Citrus jambhiri*) Lush. fruits. J Pharmacogn Phytochem. 2018; 7(5):3032–6.
155. Akamatsu S, Ogane T. Health-food product with mixed-in concentrated guava leaf extract of savouriness

- improved by cereal grain. Vol. 1. United States; US 2011/0104352 A1, 2011. p. 1-6.
156. Melton MR. Energy Drink. United States; US 2007/0172510 A1, 2007.
157. Betoret E, Sentandreu E, Betoret N, Codoñer-Franch P, Valls-Bellés V, Fito P. Technological development and functional properties of an apple snack rich in flavonoid from mandarin juice. *Innov Food Sci Emerg Technol.* 2012; 16:298-304.
158. Sridhar K, Charles AL. An integrated sustainable approach for the development of Kyoho skin functional tea. *Int J Food Sci Technol.* 2020; 55(12):3650-7.
159. Nirmal NP, Panichayupakaranant P. Antioxidant, antibacterial, and anti-inflammatory activities of standardized brazilin-rich *Caesalpinia sappan* extract. *Pharm Biol.* 2015; 53(9):1339-43.
160. Wijaya CH, Sutisna N, Nurtama B, Muhandri T, Indariani S. Development of Java tea based functional drink: Scale-up formula optimization based on the sensory and antioxidant properties. *J Appl Pharm Sci.* 2018; 8(9):55-60.
161. Indariani S, Hanny Wijaya C, Rahminiwati M, Wien Winarno M. Antihyperglycemic activity of functional drinks based on Java tea (*Orthosiphon aristatus*) in streptozotocin induced diabetic mice. *Int Food Res J.* 2014; 21(1):349-55.
162. Skąpska S, Marszałek K, Woźniak Ł, Szczepańska J, Danielczuk J, Zawada K. The development and consumer acceptance of functional fruit-herbal beverages. *Foods.* 2020; 9(1819):1-16.
163. Montonen J, Knekt P, Järvinen R, Reunanen A. Dietary antioxidant intake and risk of type 2 diabetes. *Diabetes Care.* 2004; 27(2):362-6.
164. Pasupuleti VK, Anderson JW, editors. Nutraceuticals, glycemic health and type 2 diabetes. In John Wiley & Sons, Ltd.; 2008. p. 1-498.
165. Karna P, Chagani S, Gundala SR, Rida PCG, Asif G, Sharma V, et al. Benefits of whole ginger extract in prostate cancer. *Br J Nutr.* 2012; 107(4):473-84.