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Herbal beverages: Bioactive compounds and their role in disease risk reduction - A review

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ABSTRACT

There is a renewed interest in non-nutritive bioactive compounds of foods and beverages as 'lifespan nutrients' in the risk reduction of non-communicable diseases. Herbal beverages, consumed as part of a balanced diet, may improve the antioxidant status and enhance the overall health status. Herbal teas/beverages are rich sources of natural bioactive compounds such as carotenoids, phenolic acids, flavonoids, coumarins, alkaloids, polyacetylenes, saponins and terpenoids, among others. A wealth of available scientific evidence demonstrates that natural bioactive compounds render a number of diversified biological effects, such as antioxidant, antibacterial, antiviral, antiinflammatory, antiallergic, antithrombotic and vasodilatory actions, as well as antimutagenicity, anticarcinogenicity and antiaging effects. A number of herbal beverages are consumed globally and some beverages have gained more popularity than others depending on their geographical origin. However, in the era of globalization, ethnic barriers have gradually been removed and such commodities although from different areas, are now universally available as international health-pro products.

1. Introduction

Excessive generation of reactive oxygen species (ROS) in the body causes oxidative stress, an injurious process leading to the oxidation of biomolecules such as proteins, lipids, carbohydrates and DNA. Oxidative stress is well known for its pivotal role in the etiology of several non-communicable diseases (NCDs) such as cardiovascular diseases, arthritis, type 2 diabetes, different types of cancer, autoimmune diseases and neurodegenerative disorders, among others.[1] The human body has endogenous antioxidant defense mechanisms those act simultaneously against ROS. These include enzymes (catalase, superoxide dismutase, glutathione reductase, glutathione peroxidase), low-molecular-weight antioxidants (uric acid, glutathione, albumin, protein-SH groups, bilirubin) and certain vitamins (ascorbic acid, α-tocopherol) as well as carotenoids.[2] However, external sources of antioxidants are needed to prevent oxidative damage in the human body once internal antioxidant defense systems are challenged by over exposure to free radicals and other ROS.

There is a renewed interest in natural non-nutrient antioxidative compounds in reducing the incidence and severity of NCDs. Antioxidant compounds are widely distributed in plant materials, animal tissues and microorganisms. Fruits, vegetables, cereals, legumes, oilseeds, teas and certain spices are important sources of plant-derived antioxidants.[3]

Herbal beverages, commonly known as teas, have gained popularity among health conscious consumers. They have penetrated into an emerging niche market along with other popular beverages such as tea, coffee and cocoa which are also prepared using plant materials. In addition, a rapidly growing segment of the population uses herbal beverages for slimming, weight loss and a number of other cosmetic purposes.

In general, herbal beverages are prepared from natural ingredients of different morphological plant parts, namely leaves, stems, roots, fruits, buds and flowers. Herbal teas/beverages are rich sources of natural bioactive compounds such as carotenoids, phenolic acids, flavonoids, coumarins, alkaloids, polyacetylenes, saponins and terpenoids, among others. Scientific evidence shows

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that these bioactive compounds render a myriad of biological effects, such as antioxidant, antibacterial, antiviral, antiinflammatory, antiallergic, antithrombotic and vasodilatory action, as well as antimutagenicity, anticarcinogenicity and antiaging effects, among others.[4–6] This contribution provides an overview of constituent antioxidants, and bioactivities of herbal beverages.

1.1. Antioxidants

Antioxidants are known for their ability to inhibit or delay the oxidation of other molecules in food and biological systems. They are protective against oxidative stress via different mechanisms and modes of action that are often independent of their antioxidant effect and may render their effects cooperatively via several mechanisms. These modes of action include free radical scavenging, singlet oxygen quenching, inactivation of peroxides and other ROS, metal ion chelation, quenching of secondary oxidation products, and inhibition of pro-oxidative enzymes, among others.[7]

Antioxidants are naturally present in many foods. Further, they can be synthesized, similar to their natural counterparts, such as synthetic vitamins C and E. Synthetic antioxidants generally contain of a phenolic ring and one or more hydroxyl substituents. Synthetic antioxidants that are still used by the food industry include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and *tert*-butylhydroquinone (TBHQ). However, there are concerns associated with potential carcinogenic effect of some of these synthetic antioxidants at high concentrations in animal models which limits their use in food applications and a desire by the consumers to have green label products devoid of synthetic additives.[7]

1.2. Herbal beverages

The commonly used tea is a beverage made from leaves and buds or twigs of the plant *Camellia sinensis*, and is only second to water, the most consumed beverage in the World. There are basically four major types of true teas, namely black tea, oolong tea, green tea, and white tea. Nevertheless, the term herbal tea/beverage usually refers to infusions with fruit or other herbs that do not contain *Carmellia sinesis*. Herbal beverages are also called tisane, herbal infusion, or botanical infusion to avoid confusion with true teas. Herbal beverages can be made with fresh or dried flowers, immature fruits, leaves, seeds, and/or roots by steeping (infusion) or boiling (decoction) of the source materials including herbs.

Herbal beverages when consumed within a balanced diet, may improve the antioxidant status, and reduce oxidative stress in humans.[8] In addition, many commonly consumed herbal beverages do not contain any detectable caffeine levels as in coffee and tea. Health Canada categorizes herbal beverages under natural health products (NHPs). However, according to Health Canada moderate consumption (2–3 cups/day) of selected herbal teas such as citrus peel, lemon balm, ginger, orange peel and rosehip is recommended during pregnancy and breastfeeding.[9]

Herbal beverages have been used as natural part of the food culture in countries where traditional medicines are widely used. For instance, herbal teas prepared from *Aegle marmelos* (Bael), *Cassia auriculata* (*Ranawara*), *Aerva lanata (Polpala*), and *Hemidesmus indicus (Iramusu)* are common social beverages of food cultures in India and Sri Lanka. China is another country where combined herbal teas are often drank on a daily basis to promote health and reduce the risk of certain health-related issues of different severity as simple as cold to diseases of liver and other organs.

Herbal teas consist of one or more herbal substances intended for oral consumption and prepared by means of decoction, infusion or maceration. Generally the tea is prepared immediately before use. However, ready-to-serve bottled herbal beverages are becoming popular. Herbal teas are usually supplied in bulk form or in sachets. The herbal substance (s) used in tea formulations may be processed in advance by means of drying, comminuting and crushing. Therefore, commercially available products may be in different forms such as whole dried plant parts, dried powder, dried particles within tea bags, as well as granulates, and solutions which can be consumed directly. Table 1 presents selected examples of herbal beverages commonly used by populations around the world to boost optimum health as well as for reducing the risk of a number of disease conditions such as hyperglycemia, dyslipidaemia, cancer, and hypercholesterolemia.

2. Antioxidant compounds in herbal beverages

2.1. Phenolic compounds

Phenolic compounds are ubiquitous in plant organs. They are secondary metabolites consisting of an aromatic ring with different degrees of hydroxylation.[3] Phenolics are derived from biosynthetic precursors such as pyruvate, acetate, aromatic amino acids such as phenylalanine and tyrosine, acetyl CoA and malonyl CoA following the pentose phosphate, shikimate, and phenylpropanoid metabolism pathways.[10] Phenolic compounds occurring in herbal beverages include phenolic acids, coumarins, flavonoids, tannins, lignans and lignins.

2.2. Phenolic acids

Two classes of phenolic acids, hydroxybenzoic acids and hydroxycinnamic acids are found in plants.[3] Hydroxybenzoic acids (C_6-C_1) include gallic, *p*-hydroxybenzoic, vanillic, syringic, and protocatechuic acids, among others. The hydroxycinnamic acids, better known as pheylpropanoids (C_6-C_3), include *p*-coumaric, caffeic, ferulic, and sinapic acids.[3] Herbal beverages have been reported to include a number of phenolic acids.

2.3. Flavonoids

Flavonoids are synthesized by condensation of a phenylpropanoid compound with three molecules of malonyl coenzyme A. This reaction is catalyzed by the enzyme chalcone synthase that leads to the formation of chalcones. The chalcones are subsequently cyclized under acidic conditions to form flavonoids.[3] There are different subclasses of flavonoids, namely flavones, flavonols, flavonones, flavononols, isoflavones, anthocyanidins and flavanols. Flavones and flavonols are present as aglycones in foods.[3] They have similar C ring structures with a double bond at the 2–3 positions. Flavones lack a hydroxyl group at the third position.[3] Flavonols (quercetin, kaempferol, and myricetin), flavones (luteolin, apigenin and chrysin), flavanols (catechin, epicatechin, epigallocatechin, epicatechin gallate, and epigallocatechin gallate), flavanones (narigenin, hesperitin, and eriodictyol), anthocyanidins (cyanidin, malvidin, peonidin, petunidin, pelargonidin and dephinidin), and isoflavones (genistein, daidzein, and glycitein) are the commonly found flavonoids in the human diet. Flavonoids, namely catechin, quercetin, kaempferol, rutin, apigenin, and isorhamnetin are constituents of the aqueous infusions of flower, leaf and seed of *Sideritis condensate*[11] (Table 2). In addition, flower infusion prepared within 10 min time contained 15 mg of isorhamnetin per gram of dry matter.

Table 1
Selected Herbal beverages commonly consumed in different parts of the world.

Local name	Scientific name	Family	Plant part	Health benefits
Beli, bael, bengal quince	*Aegle marmelos*	Rutaceae	Dried leaves, buds, flowers, immature fruits, bark	Anticancer, antidyslipidaemia,antihyperglycemic, antidiabetic, antiinlammatory,
Tanner's Cassia, *Avartaki*, *Ranawara*	*Cassia auriculata*	Leguminosae	Dried leaves, flowers	Antihyperglycemic
Polpala	*Aerva lanata*	Amaranthaceae	Dried whole plant	Antihyperglycemic, antiinlammatory
Indian Sarasaparilla, *Iramusu*	*Hemidesmus indicus*	Asclepiadaceae	Dried whole plant	Antioxidant, antithrobotic, antiplatelet aggregation
Pegaga, Indian pennywort, *Gotukola*	*Centella asiatica*	Apiaceae	Dried whole plant	Anticancer, increase the activity of antioxidant enzymes
Chamomile	*Matricaria chamomilla Chamaemelum nobile*	Compositae	Dried flowers	Antioxidant, hypocholesterolemic, anticancer, antiinlammatory
Heart leaved mooseed	*Tinospora cordifolia*	Menispermaceae	Stem, roots	Antidiabetic, antiinlammatory
Corriandum	*Coriandrum sativum*	Apiaceae	Dried fruits	Antioxidant, antibacterial, hypocholesterolemic, anticancer, antiinlammatory
Dag cayi	*Sideritis condensate*	Lamiaceae	Dried aerial parts	Antioxidant, antibacterial
Peppermint tea	*Mentha piperita*	Lamiaceae	Dried leaves	Antioxidant, antitumor
Yerba mate	*Ilex paraguariensis*	Aquifoliaceae		hypocholesterolemic,hepatoprotective, cardiovascular system protective
Sage, adacayi, minchi	*Salvia officinalis*	Lamiaceae		Increase liver antioxidant status
Rosehips	*Rosa canina*		Fruits	Antiinlammatory
Rooibos	*Aspalathus linearis*			Antioxidant, anticancer
Borututu	*Cochlospermum angolensis*		Roots	Antihepatocelluar carcinoma, antioxidant
Ginger	*Zingiber officinale*		Rhizome	Antiinlammatory, hypoglycemic

2.4. Lignans

Lignans are compounds that comprise of two coupled phenylpropanoid units linked by the central carbons of their side chains.[3] The common plant lignans found in the human diet include secoisolariciresinol, matairesinol, lariciresinol, pinoresinol and syringaresinol.[12] Secoisolariciresinol, and matairesinol are readily converted to mammalian lignans, enterodiol and enterolactone, respectively, by intestinal microflora in the human gut and are known to exert strong antioxidant and estrogenic activities.[12]

2.5. Lignins

Lignins are formed via polymerization of a mixture of the three monolignols, namely *p*-coumaryl, sinapyl and coniferyl alcohols.[13] Additional compounds are incorporated into lignin in small quantities. They include coniferaldehyde, sinapaldehyde, dihydroconiferyl alcohol, 5-hydroxyconiferyl alcohol, tyramine ferulate and *p*-hydroxy-3-methoxybenzaldehyde, among others.[14]

Table 2
Phenolic acids and flavonoid contents of *Sideritis condensate* steeped at 100 C for 10 or 30 min.

Phenolic compound	Plant part	μg/g of dry weight
Phenolic acids		
Protocatechuic	flower	200
p-Hydroxybenzoic	flower	1178
Vanillic	flower	1569
p- Coumaric	seed	249
Caffeic	leaf	601
Ferulic	flower	59
Flavonoids		
Catechin	leaf	209
rutin	leaf	879
Quercetin	flower	1902
kaempferol	leaf	1057[a]
Isorhamnetin	flower	15284[a]

Source: Data adapted from Kara et al.[11].
[a] Steeping for 10 min.

2.6. Tannins

Tannins are composed of a group of compounds with a wide diversity in structure and have ability to bind and precipitate proteins.[3] Tannins are classified into three groups, namely condensed tannins, hydrolysable tannins and complex tannins.[15]

2.7. Coumarins

Coumarins are lactones of cis-*O*-hydroxycinnamic acid derivatives and exist in the free form or as glycosides. In foods, simple coumarines, furanocoumarines (psoralens) and pyranocoumarins are found.[3]

2.8. Terpenes

Terpenes and terpenoid derivatives are secondary metabolites which originate from isoprene (2-methylbutadiene) units.[16] The C5H8 isoprene units polymerise and subsequently produce different classes of terpenoids that include hemiterpenes consisting of a single C5 isoprene unit, monoterpenes (C10), sesquiterpenes (C15), diterpenes (C20), sesterterpenes (C25), triterpenes (C30), carotenoids (C40) and polyterpenes consisting of long chains of many isoprene units. Triterpene group of compounds include sterols and triterpenes, which are accumulated as glycosides (saponins) in plants. Saponins are glycosylated (aglycone named sapogenin) secondary metabolites with surface-active properties. Some of these saponins are valuable starting materials for the synthesis of steroidal drugs.[17]

2.9. Carotenoids

Carotenoids are widespread pigments with yellow, orange, and red colours. They have pro-vitamin A and antioxidant activities. Carotenoids belong to hydrocarbons (carotenes) with a 40-carbon atom skeleton of 8 isoprene units. Their structures may be cyclized at one or both ends, and have different number of hydrogen atoms, or possess oxygen-containing functional groups,

the latter named as xanthophylls. Common carotenes in the human diet include β-carotene, α-carotene and lycopene, whereas xanthophylls include lutein, zeaxanthine, cryptoxanthin, canthaxanthin, astaxanthin and fucoxanthin. Major provitamin A active carotenoids are β-carotene, α-carotene and cryptoxanthin.

2.10. Polyacetylenes

Polyacetylenes are a group of bioactive compounds consisting of carbon-carbon triple bond or alkynyl functional group.[18] Aliphatic C_{17}-polyacetylenes of the falcarinol type such as falcarinol and falcarindiol are widely distributed in the Apiaceae and Araliaceae families. Polyacetylenes of the falcarinol-type are formed from oleic acid by dehydrogenation that leads to the formation of C_{18}-acetylenes crepenynic acid and dehydrocrepenynic acid, which are then transformed to C_{17}-acetylenes upon β-oxidation.[18] Health promoting properties and the content of polyacetylenes of a number of traditional medicinal herbs have been investigated during past few decades. Herbs such as American ginseng root (*Panax quinquefolium*), *Peucedanum praeruptorum*, *Echinacea pallida*, *Bupleurum spinosum* and *Atractylodes lancea* have been reported to contain polyacetylenes[19–22].

3. Antioxidant activities and bioactivities of herbal beverages

Herbal teas have been consumed as social drinks for centuries. In addition they are also used as alternative herbal medicines to treat a number of ailments. In the modern societies they are used for reducing the risk conditions of non-communicable diseases such as type 2 diabetes, hypertension, dyslipidemia and cancer.[23–36] Table 3 summarizes selected information on medicinal claims for herbal concentrates of *A. marmelos*.

3.1. Asian herbal teas

Centella asiatica is an herbal tea commonly used by Asian populations. The dried whole herb as a single ingredient or mixed with other products such as garlic, coriander or ginger is used. This herb is known to increase the activity of antioxidant enzymes, namely superoxide dismutase, catalase, and glutathione peroxidase.[37] *C. asiatica* consists of a number of bioactive compounds such as alkaloids, terpenoids and saponins.[38] The principle triterpenoids identified in this herb include asiatic acid, madecassic acid, asiaticoside and madecassoside, among others.[39] In addition, *C. asiatica* is a rich source of bioactive polyacetylenes.[18] Govindan et al.[40] identified a polyacetylene compound, cadiyenol, from the areal part of the plant. They further demonstrated that cadiyenol was capable of inducing cell apoptosis by 63% at 28 μM concentration within 24 h in mouse lymphoma cells (P388D1). In addition, the compound also reduced nitric oxide production by 70% in lipopolysacahrride (LPS) activated mouse macrophages at 24 μM level.

In Japan, a number of herbal teas such as Arabian jasmine, Balsam pear, barley grass, guava, hardy rubber tree, Japanese persimmon, Jobs tears, and Wolof berry tea are consumed for health promotion.[41] Total phenolic content of Arabian jasmine, balsam pear, barley grass, chameleon plant, guava, hardy rubber tree, Japanese persimmon, jobs tears, and wolf berry tea were 101, 15, 11, 83, 43, 41,4 and 17 mg tannic acid equivalents (eq)/g of herb (dry weight), respectively. The antioxidant activity of these herbal teas ranged from 7 to 173 mmol/L as copper reducing power.

A. marmelos, commonly known as bael, is a plant native to Southeast Asia. It is a slow growing, subtropical tree and is grown in India, Sri Lanka, Pakistan, Bangladesh, Burma, Thailand, and other Southeast Asian countries. Bael fruit is a rich source of coumarins, vitamin C, and riboflavin. The leaves, stems, and bark as well as fruits are known in traditional medicine for dysentery and various other intestinal complaints (Plate 1). The leaves are also widely used to treat diarrhoea. In addition, bael is a potent radioprotective, analgesic, antihyperglycemic, antidyslipidemic, anticancer, and antidiabetic agent.[42–47] The total phenolic content (TPC) and total flavonoid content (TFC) of bael fruit were reported to be 87 mg gallic acid eq/g of dry weight (dw) and 15 mg catechin eq/g dw, respectively.[48] In addition, the content of carotenoids and ascorbic acid of bael fruit were reported to be 3.3 and 26 mg/100 g dw, respectively. Furthermore, monoterpenes (limonene, pulegone) and sesquiterpenes (cubebene) were reported as its dominant volatile compounds.[48] Limonene is the major constituent producing the characteristic bael fruit flavor, among others. In addition, coumarins such as marmelosin, marmesin, and imperatorin, as well as alkaloids, namely aeglin, and aegelenine were also isolated from different parts of bael.[49] The extract of leaf, root, stem and the fruit demonstrated high antioxidant activities as determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity, and ferric reducing antioxidant activity power (FRAP) assays. Furthermore, several bioactivities such as antidiabetic, antihyperlipidemic, antiviral, antifungal, antibacterial, anticancer, and anti-inflammatory were reported in association with different parts of bael tree.[26,50] The antidiabetic effect of the fruit extract is probably due to the presence of coumarins, which potentiate insulin secretion from existing beta cells of the isles of langerhans.[51] In Sri Lanka, dried buds and flowers and immature fruits are prepared as herbal tea infusions to replace the popular tea prepared from *Camelia sinensis*.

Generally bael is considered to be safe but only few studies have been conducted on its toxicity. Das et al[52] examined the toxic effects of aqueous extract of the leaves of bael and reported that 50 mg/100 g of body weight of male albino Wistar strain rats did not exhibit any toxicity in the liver and kidneys. Further, it was demonstrated that neither gross abnormalities nor

Table 3
Evidences on medicinal claims for *Aegle marmelos*.

Plant part	Outcome	Reference
Leaf extract	antidiabetic action in hyperglycaemic rats	Sachdewa et al.[23]; Ponnachan et al.[24]; Upadhya et al.[25]
	Reduced cholesterol level in diabetic patients	Gohil et al.[26]
	Radioprotective effects in mice	Jagetia et al.[27]
	Antihyperlipidaemic effect in rats with isoproterenol -induced myocardial infarction	Rajadurai and Prince[28]
Root extract	Anti-inflammatory activity in animals	Benni et al.[29]
Fruit extract	Diuretic activity in rats	Singh et al.[30]
	Antidyslipidemic effects in rats	Krushna et al.[31]
	Reduces intraocular pressure, a cause for glaucoma in New Zealand white rabbits	Agarwal et al.[32]
	Hypoglyceamic activity in diabetic rats	Kamalakkannan and Prince[33]
	antidiabetic action in rats	Kamalakkannan and Prince[34]
	Chemopreventive effect in Swiss albino mice	Agarwal et al.[35]
Bark extract	Antifertility activity in male Wistar rats	Agarwal et al.[36]

Plate 1. Fresh flower and buds of Tanner's Cassia and cuttings of dehydrated immature fruit and preparation of herbal tea of bael.

histopathological changes were observed in the heart, liver, kidneys, testis, spleen and brain after continuous administration of 50 mg/kg body weight of the extracts of *A. marmelos* intraperitoneally for 14 d.[53] In addition, the aqueous extract of bael fruit was not reported to be mutagenic to *Salmonella typhimurium* strain TA 100 in the Ames assay.[54]

Dried flower buds, flowers and leaves of Tanner's Cassia (*Cassia auriculata*) have gained wide popularity as herbal teas in countries such as India and Sri Lanka. Furthermore, plant parts of Tanner's Cassia have been used as an alternative therapeutic agent particularly in controlling hyperglycemic conditions in traditional medical system. Methanolic extracts of Cassia flowers inhibited α-glucosidase activity *in vivo* and *in vitro*.[55] Further, the flower and leaf extracts of Cassia exhibited antihyperglycemic effects in streptozotocin-induced experimental diabetes.[56,57] In addition, the aqueous extract of Cassia inhibited lipid peroxidation in the brain of diabetic rats.[58] Several phenolic compounds, namely (-) catechin, (-) epicatechin and procyanidin B_1 were identified in aqueous alcoholic extract of cassia seeds.[59] Puranik et al.[59] reported on cardiovascular safety and good tolerance of Cassia seed extracts without any adverse effects in male and female rats. However, Cassia seed extracts obtained using supercritical fluid extraction interfered with the absorption of metformin when co-administered with extracts in a rat model.[59]

3.2. Herbal teas popular in Africa

African rooibos (*Aspalathus linearis*), borututu (*Cochlospermum angolensis*) and honey bush tisanes are popular South African herbal teas. Traditional medicinal uses of rooibos in South Africa include alleviation of infantile colic, allergies, asthma and dermatological problems. Furthermore, decoction of honey bush is used as a restorative and as an expectorant in chronic catarrh and pulmonary tuberculosis.[60] Mckay and Bulmbergare[61] reported that rooibos is rich in polyphenols and a rare source of the dietary dihydrochalcones, namely aspalathin and nothofagin. In addition, major polyphenols in honey bush are xanthone mangiferin and the flavonones, hesperitin and isokuranetin.[62] Both rooibos and honey bush teas have demonstrated potent antioxidant and antimutagenic activities *in vitro*. Rooibos tea also renders beneficial effects for heart health. It was reported that chrysoeriol, which is present at low levels in Rooibos is a potential agent in preventing and treating vascular diseases in humans.[63] Chrysoeriol is able to inhibit the migration of smooth muscle cells inside the aorta, a key cause of atherosclerosis. Furthermore, Rooibos tea has demonstrated ACE (angiotensin converting enzyme) inhibitory activities and reducing several of the pertinent biomarkers associated with cardiovascular disease.[64,65]

3.3. Herbal teas popular in South America

Yerba mate (*Ilex paraguariensis*) is widely consumed by native people as social and medicinal beverage in South America for centuries and unlike other herbal beverages it contains caffeine. Several health promoting properties such as hepatoprotective, diuretic as well as central nervous system stimulating effects have been reported for yerba mate.[66] Furthermore, other studies have demonstrated its antioxidant, anti-inflammatory, antimutagenic and lipid lowering activities.[67–70] The main bioactive compounds in yerba mate responsible for its activities were identified as caffeoyl derivatives such as caffeic acid, mono- and dicaffeoylquinic acids, methylxanthines (caffeine and theobromine) and flavonoids, namely rutin, quercetin and kaempferol.[71] In a separate study, it was demonstrated that yerba mate and its bioactive compounds regulate the expression of genes related to adipogenesis.[72] Yerba mate extract down-regulated the expression of genes responsible for adipogenesis, such as Creb-1 and C/EBPα. Furthermore, the extract up-regulated the expression of genes related to the inhibition of adipogenesis, including Dlk1, Gata2, Gata3, Klf2, Lrp5, Pparγ2, Sfrp1, Tcf7l2, Wnt10b, and Wnt3a.[72]

Table 4
Oxygen radical absorbance capacity (ORAC) and cellular antioxidant activity (CAA) of herbal beverages.

Herbal beverage	ORAC (μmol trolox eq/g dw)	CAA (μmol quercetin eq/g dw)
Peppermint tea	1438	27.9
Sage	1351	35.3
Yerba mate	1195	46.5
Rosehip	330	2.9

Source: Data adapted from Bender et al.[83].

Kombucha tea is a health beverage prepared by fermentation of black tea brew and sugar with a symbiotic culture of acetic acid bacteria and yeasts reported to have potential health effects.[73] Aloulau et al[73] demonstrated that compared to black tea, kombucha tea was an effective inhibitor of α-amylase and lipase activities in the plasma and pancreas of diabetic rats. Further, kombucha tea demonstrated higher suppressor activity of increased blood glucose levels than that of black tea. In addition, kombucha induced a marked delay in the absorption of LDL-cholesterol and triglycerides and a significant increase in HDL-cholesterol. According to histological analysis it exerted an ameliorative action on the pancreases and efficiently protected the liver-kidney functions of diabetic rats. This was further evidenced by significant decreases in aspartate transaminase, alanine transaminase, and gamma-glytamyl transpeptidase activities in the plasma, as well as in the creatinine and urea contents of diabetic rats.[73]

3.4. Herbal teas popular in Europe

Chamomile is a member of Asteraceae or Compositae family and is represented by several varieties, namely *Chamomilla recutita, Matricaria chamomilla* and *Chamaemelum nobile*. Chamomile tea is widely consumed in Europe. Chamomile tea, is brewed from dried flower heads. The main constituents include phenolic compounds, primarily the flavonoids apigenin, quercetin, patuletin, and luteolin.[74] The principal compounds of the essential oil are the terpenoids alpha-bisabolol and azulenes, including chamazulene. Chamomile has moderate antioxidant and antimicrobial activities, and significant antiplatelet activity *in vitro*.[74] In addition, animal studies have shown potent anti-inflammatory, antimutagenic and cholesterol-lowering activities for chamomile. Furthermore, some antispasmotic and anxiolytic effects of chamomile tea have also been demonstrated.[74]

Several studies have shown the antioxidant, hypocholesterolemic, anti-parasitic, anti-aging, and anticancer properties of chamomile.[75–77] Chamomile has long been known as a treatment for inflammatory diseases. It was demonstrated the chamomile treatment inhibited the release of LPS-induced prostaglandin E $(_2)$ in RAW 264.7 macrophages *in vitro*.[77] This effect was found to be due to inhibition of COX-2 enzyme activity by chamomile extracts. Furthermore, chamomile caused reduction in LPS-induced COX-2 mRNA and protein expression, without affecting COX-1 expression.[77] A small percentage of people are sensitive to chamomile and develop allergic reactions.[78] Evidence of herb-drug interactions of chamomile is not well documented, and further studies are needed to reach any final conclusions.[78]

'*Dagcayi*' is a popular herbal beverage in Turkey prepared from infusion of *S. condensate*. In a recent study, phenolic composition of aquous infusions of *Dagcayi* was reported.[11] Dried aerial part of the plant is generally used to infuse the tea. Hydroxybenzoic as well as hydroxycinnamic acids were identified in flower, leaf and seed extracts of *S. condensate*. Phenolic composition of *S. condensate* changed based on the infusion temperature, time duration and part of the plant used for infusion. The phenolic acid identified in all plant parts examined was *p*-coumaric acid and its content ranged from 10 to 398 μg/g of dry matter of different plant parts, namely flower, leaf and seed. Chlorogenic acid was detected only at the steeping temperature of 60 °C.[11]

Peppermint tea, brewed from *Mentha piperita* leaves, is a commonly consumed tisane that gives calming effect in the body and is popular in Europe and North Africa. Health benefits reported for peppermint tea include *in vitro* antibacterial activity against a range of pathogenic bacteria and antioxidant activity.[79,80] The phenolic compounds reported in the leaves of *M. piperita* include rosmarinic acid and flavonoids.

Several preparations of rosehip fruits and seeds (*Rosa canina*) demonstrated antioxidant and antiinflammatory activities.[81] *R. canina* L. fruits have a high content of ascorbic acid, and phenolics, including flavonoids, which render antioxidant activity as well as several other beneficial bioactivities.[82]

According to Bender et al.,[83] *in vitro* oxygen radical absorbance capacity (ORAC) and ex *vivo* cellular antioxidant capacity (CAA) of yerba mate, peppermint tea, sage and rosehip fruit infusions in HaCat human keratinocytes cell line were found to vary considerably (Table 4). Sage (*Salvia officinalis*) is commonly used to prepare beverages as well as a flavoring agent in foods. Several health benefits such as antitumoral, antibacterial and antiinflammatory properties of sage have been reported.[84,85]

Herbal beverages are habitually used as part of the normal diet in some populations in the world and trend of using them among others is progressively increasing. However, very limited published information is available on safety of herbs and herbal beverages, and herb-herb as well as herb-therapeutic drug interactions. It should be noteworthy that herbal beverages are prepared to maintain plalatable chracteristics of a social beverage thus they are less strong in their flavour and their bioactive compounds are present in smaller amounts due to the dilution as compared to those of herbal preparations intended to use as medicine. For instance, in Sri Lankan traditional and Ayurvedic medical system decoctions to be used as medicine are prepared by boiling dried or fresh herbs in 8 cups of water until volume is reduced to one cup.

According to a review by Singh et al[86] the herb *C. asiatica* might cause liver problems, stomach upset, nausea, and drowsiness. Choi et al[87] reviewed the herb drug interactions and specially focused on the effect of herbs on metabolic enzymes and transporters. Active compounds of some herbs may inhibit phase 1 and 2 metabolic enzymes thus affect the drug metabolism. In addition, concentrated form of some herbs, such as green tea can cause detrimental effects, namely liver damage, interaction with medications, interaction with metabolic enzymes and other natural ingredients.[88,89]

4. Summary

Herbal beverages are potential rich sources of phytochemicals that may help in reducing disease risk conditions and therefore in the management of NCDs. A number of herbal beverages are consumed globally. Though bioactivities of some herbal beverages are known through preclinical studies, further analytical and clinical research is warranted in order to investigate the bioactive compounds that render such effects and their mode(s) of actions in

disease risk reduction and health promotion needs to be verified.

Conflict of interest

There are no conflict of interest to report.

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