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Bioactivity of fruit teas and tisanes – A review

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Abstract
In recent times, there is a growing interest in nutrition and preventive health care in the development and evaluation of natural bioactive and antioxidant active products from plant materials. Tea, the commonly drunk beverage after the water has significant quantities of polyphenols, vitamins, amino acids, volatile compounds. It is well documented that green tea contains substantially higher amounts of polyphenol substances than black tea, which are known for their radical scavenging capacity. Tisanes are basically the herbal tea made from addition of herbs to the black tea or the green tea. Likewise fruit teas are made by addition of fruits like lime, pomegranate, blueberry, apple in a given ratio as preferred by the manufacturer. This article provides a critical review on different polyphenolic compounds and the antioxidant properties present in various fruit/herbal teas available in the local and international market.

Keywords: *Camellia sinensis*, tisanes, fruit tea, polyphenols, infusions

Introduction
Tea is a popular, cheap, non-alcoholic beverage which is loved around the world while being one of the most profitable commercial crops of Sri Lanka, the country being the third largest producer of tea across the globe. As one of the leading tea exporters, contribution of tea for generation of foreign exchange to Sri Lanka is highly significant. At the mean time it secures the livelihoods of people. Tea has a history of 150 years in Sri Lanka. It is cultivated in high, low and medium elevations. There are six agro climatic regions where tea is grown in Sri Lanka namely Kandy (medium grown), Nuwara Eliya, Dimbulla, Uda Pussellawa (High grown), Ruhuna (Low grown), Uva (high and medium grown) (Tea board annual report, 2011) [1].

Tea has been mentioned as the medicinal beverage which yields significant health benefits upon regular consumption such as the prevention of cardiovascular diseases, cancer prevention, promoting oral health, and promotion of digestive health (Tanaka, 2009)[32].The presence of significant quantities of polyphenols and flavonoids account for the medicinal value of tea. The types of tea produced from *Camellia sinensis* (white, green and black) differ in the processing of the plant material (Bhatt *et al*., 2010) [4].

Types of Teas
Hundred of teas are now produced and are classified into three main categories: non fermented green tea, partially fermented oolong and paochong tea, and fully fermented black tea and puerh tea (Dwyer, 2013; Lin *et al*. 2003) [11, 15]. Green tea is made by leaves heated immediately after harvesting, mechanically wound and compressed, and then the leaves are dried to ensure the preservation of color and natural constituents (Turan & Kennedy, 2002; Pereira *et al*, 2014) [32, 23]. Black teas are produced through complete fermentation. Where Catechins amount to approximately 20% on dry weight and hence regarded as the major biochemical constituent present in tea leaves. They get oxidized to form theaflavins and thearubigins as a result of condensation during fermentation (action of polyphenol oxidase) (Asil *et al*. 2012; Wilson *et al*., 2016) [2, 35]. Fermentation stage in black tea accounts for its characteristic aroma and colour. Theaflavins contribute to the sensory characteristic bright orange-red color of black tea (Mitra, 2015) [28]. Four major theaflavins found are theaflavin, theaflavin-3-gallate, theaflavin-3'-gallate, and theaflavin-3, 3'-digallate (Engelhardt, 1989; Kim *et al*, 2016) [31, 14].

The white tea has a particular method of post-harvest processing, containing a greater proportion of sprouts, which are covered with a thin layer of silvered hair characterizing the tea coloring (Pereira *et al*., 2014) [23]. Unlike black and green teas, white tea is not rolled or crushed, but is slightly fermented, cooked quickly and its leaves are dried naturally in air to preserve the most polyphenols. The total polyphenol content of green and black teas is similar, but with different types of flavonoids present due to the degree of oxidation during processing

(Mukhtar, 2014) [19].Oolong tea is produced by subjecting the tea leaves to shorter period of oxidation compared with black tea. Therefore it is referred to as half fermented tea with considerable amounts of polyphenols between green tea and black tea (Sai *et al*. 2011; Nibir *et al*. 2017) [25,20].

Tea is either manufactured from CTC or Orthodox methods where in Sri Lanka orthodox is the most preferred to the date. CTC being the fastest way of tea manufacture, where all the oxidisable polyphenols are converted to theaflavin and thearubigin while in Orthodox teas quarter of them remain unchanged (Linskens, 2012) [6].

The main catechins of green tea are: (+)-catechin (C), (-)-epicatechin (EC), (-)-gallocatechin (GC), (-)-epicatechin gallate (ECG), (-)-epigallocatechin (EGC), (-)-epigallocatechin gallate (EGCG). (Chacko *et al*., 2010; Mukhtar *et al*, 2014) [8,19]. Experimentally it has been found that a catechin level (EGCG, EGC, ECG, EC, C) lowers gradually during fermentation, however, the level of gallic acid grows. The levels of theaflavins and thearubigens also decrease gradually, while the level of caffeine increases in the process of 85% fermentation from 8.69 to 16.03 mg/100 mg of leaf dry weight (Gramza *et al*. 2005) [9].

Green tea leaves consist of flavonoids as well as phenolic acids which can make up to 30% of fresh leaves dry weight and only 10% of dry weight of black tea (Gramza *et al*., 2005) [9]. Enzymatic or non-enzymatic oxidation is the most common reaction involved in the production of secondary polyphenols (Tanaka, 2009) [32].

There chemical constituents of *Camellia sinensis* tea, comprise polyphenols, methylxanthines (caffeine, theophylline and theobromine), vitamins, amino acids, carbohydrates, proteins, chlorophyll, volatile compounds, fluoride, minerals, trace elements, and other undefined compounds. Polyphenols are compounds of great interest because they present potent antioxidant activity both *in vitro* and *in vivo* due to its reducing properties (Pereira *et al*, 2014) [23]. Antioxidative properties of phenolic compounds are manifested particularly by their abilities to inhibit free radical generation, scavenge free radicals, and chelate transition metal ions, mainly iron and copper, which are catalysts of free radical reactions. They also prevent free radical generation by inhibiting activity of existing enzymes or by increasing the activity of enzymes with antioxidative properties, probably on the way of induction of protein molecule biosynthesis (Pyrzynska, 2017) [30]. It has been stated in the Chinese herbal documentary that tea can detoxify 72 toxicants (Bidlack *et al*., 2000) [5].

Because of the great number of antioxidative compounds it is rather easier to determine the total andioxidative capacity (Pyrzynska, 2012) [22]. The advances in gas chromatography and combined gas chromatography-mass spectrometry show that more than 630 compounds have been reported responsible in tea aroma. Though tea contains many amino acids, theanine is the most abundant, accounting for 50% of the total amino acids. Amino acid degradation is involved in the biogenesis of the tea aroma (Sai *et al*. 2011) [25].

The chemistry of tea

Various types of teas are being manufactured from the leaves of the tea plant, *Camellia sinensis*. There are more than 400 compounds present in tea leaves identified so far. The contents can vary upon the climate, soil, season, horticulture practices and the age of the leaf (Saito *et al*., 2006) [27]. Green tea which is made by drying or steaming of fresh leaves at higher temperatures is said to have the same chemical composition as the fresh tea leaves, with high content of polyphenols. (Bidlack *et al*., 2000) [5].

Table 1: Composition of tea leaves

Polyphenols	36.0%	Carbohydrates	25.0%
Methylxanthines	3.5%	Protein	15.0%
Amino acids	4.0%	Lignin	6.5%
Organic acids	1.5%	Lipids	2.0%
Carotenoids	< 0.1%	Chlorophyll	0.5%
volatiles	< 0.1%	Ash	5.0%

Source: (Turan & Kennedy, 2002) [34]

Table 2: The difference in composition of green and black made tea.

Components	Green Tea	Black tea
Catechins	30-42%	3-10%
Flavonols	5-10%	6-8%
Other flavonoids	2-4%	-
Theogallin	2-3%	-
Gallic acid	0.5%	-
Quinic acid	2.0%	-
Theanine	4-6%	-
Methylxanthines	7-9%	8-11%
Theaflavins	-	3-6%
Thearubigens	-	12-18%

Source: (Turan & Kennedy, 2002) [34]

A study carried out by Nibir *et al*. 2017 [20] where samples of different black tea grades such as FBOP, BOP, Dust and green tea analyzed for the total phenolic contents and the total flavonoids contents. The Total phenolic content and flavonoids contents ranged 6.78 ± 0.55 - 8.84 ± 0.50 mg GA/g, 13.93 ± 1.08 - 19.12 ± 0.33 mg catechin/g extract for black teas and 26.33 ± 1.73 mg GA/g, 50.12 ± 0.60 mg catechin/g for green tea. Similar patterns of results have been obtained by Pereira, 2014 [23] where green tea showed a higher content of total phenols (55.40 mg/g), which was significantly higher from the white tea (46.91 mg/g) and black tea (36.28 mg/g).

Value addition and product diversification

The market today largely requires consistency of products. Observational studies have repeatedly shown that diets high in plant-based foods and beverages are associated with a lower risk of chronic diseases, such as cardiovascular disease and some forms of cancer (Mckay & Blumberg, 2007) [17].

Blends can be created to suit different tastes, different times of the day and different foods. Successful blending is usually the result of experimentation and tasting, trial and error. Teas can be flavoured at home by addition of a few dried flower petals, pieces of spice or dried herbs. The common blends available in the market are the Orange, Lime/lemon, country blossom, fruit and flowers, apple magic, wild cherry, strawberry etc (Clifford *et al*, 1992) [37]. Scented teas are produced by mixing with jasmine flowers, herbal teas are where green tea is mixed with medicinal plants, and organic teas too are on trend. Other special teas include, caffeine free tea, handmade teas, non-withered teas, pickled tea, instant tea (Kurian *et al*., 2007) [13].

Phenolic content of different fruit tea infusions

The popularity of flavoured tea has been increasing due to the attractive taste and the antioxidant properities. Fruits, herbs and aromatic plants are important sources of phenolic compounds such as phenolic acids, flavonoids and anthocyanins, which have considerable antioxidant properties

in vivo and *in vitro* (Pyrzynska *et al*., 2012) [22].
A study by Sahin, 2010 [26] on the total phenol, total flavonoid, and total anthocyanin contents were determined in different fruit teas – pomegranate, peach, lemon, blueberry, apple, apricot, blackberry, strawberry where the total phenol content varied from 0.96 ± 0.01 to 6.91 ± 0.47 mg GAE/g (gallic acid equivalent (GAE) in milligrams of gallic acid per gram of dried fruit tea). The pomegranate tea considered significantly higher amounts of total phenol at 100^0C extraction whereas apple tea had the lowest polyphenols content at 20^0C. Similarly the total flavonoid content varied from 1.70 ± 0.08 to 36.81 ± 0.10 mg CTE/g dried fruit tea (catechin equivalent (CTE) in milligrams of catechin per gram of dried fruit tea). Pomegranate was recognized as the richest source of total phenol content, but peach (III) was recognized as the richest source of total flavonoid content. This indicates flavonoids, which are subgroups of phenolic compounds, had lower contribution to the total phenol content than the other phenolic compounds such as hydroxycinnamic acid, hydroxybenzoic acid, etc. Blackberry contained the highest anthocyanin followed by pomegranate, strawberry etc. The antioxidant capacity measured by ABTS assay ranged from 66.39 ± 0.99 to 4.08 ± 0.10 mg TE/g dried fruit tea. High level of antioxidant capacity in pomegranate as compared to the other fruit tea could be due to its high level of total phenol content.
Among the phenolic compounds determined at water temperature of 100 °C by HPLC-DAD, Rutin was the most abundant phenolic compound determined in fruit teas. Total phenolic content, anthocyanin, antioxidant capacity and flavonoid content of fruit teas were higher with the increasing temperature for the extraction and maximum values were reported at 100 °C. It has been reported that flavonoids had a lesser antioxidant capacity than phenolic compounds. Similarly a study by Pyrzynska, 2017 who analyzed the polyphenolic contents of different tea infusions concluded that Rutin was the highest observed phenolic compound ranging from 6.30 ± 0.29 10.8 mg/l - 25.7 ± 0.072 mg/l where Citrus tea was characterized by the lowest content of that glycoside. Quercetin 0.034 ± 0.008 - 0.116 ± 0.004mg/l, Hasperidin 0.025 ± 0.005 mg/l - 0.69 ± 0.043mg/l, Naringin 0.004 ± 0.0001 mg/l - 3.51 ± 0.099mg/l.
Generally, pure black teas have more flavonoids compared to aromatized teas but according to the study the reducing power of the extracts of studied teas were in the range of 345 – 1119 mg GA/L where the black tea infusions have highest antioxidant activity.
Tea polyphenols have been reported to have strong antioxidant property and free radical scavenging activity due to possession of a phenolic hydroxyl group attached to the flavan- 3-ol structure. Free radicals are generated constantly due to metabolism of food ingredients, physical stress, and oxidative stress mediated by various environmental pollutants/ chemicals/toxins, radiation etc. These free radicals are implicated in numerous disorders in human such as cancer, angina pectoris, neurodegenerative diseases and atherosclerosis. Due to free radical scavenging activity, antioxidants are beneficial for reducing or preventing the progression of these diseases. A change in tea composition may occur while fermenting tea leaves to produce black tea, and this change might be the main cause of relative lower antioxidant potential of black tea than green tea found in our study (Nibir *et al*., 2017) [20].
Flavoured black teas contain significantly higher level of catechins, quercetin, and rutin, while the content of chlorogenic and caffeic acids as well as naringin and hesperidin was higher in fruit teas. (Pyrzynska, 2011) [7]. The antioxidant properties of studied tea infusions of flavoured black tea was higher than the that for the fruit teas and premium black teas.
According to Pyrzynska *et al*., 2012[22] who analyzed the polyphenolic content of flavoured black teas such as earl grey, peach, lemon, vanilla, citrus, tropic fruit teas etc, stated that Flavonoids are predominantly present as glycosides rather than as their non-glycosylated forms (aglycones). Only quercetin as a free aglycone was found at trace levels (0.03–0.13 mg/L) in the studied infusions; however, its content was lower than for premium black tea. Rutin (quercetin-3-rutinoside) was present at much higher level. Chlorogenic acid (from the group of hydro- xycinnamic acids) in the studied infusions was found in the relatively high amount (0.93–2.4mg/L). Hydroxycinnamic acids are almost the most abundant phenolic components in the citrus family and other fruits. Citrus, Lemon and Peach teas also contain hesperetin-7-rutinoside (hesperidin) which were not present in the premium black teas. According to McKay, 2009[18] daily consumption of 3 servings of Hibiscus tea, an amount readily incorporated into the diet, effectively lowered BP in pre and mildly hypertensive adults.
An experiment carried out analyzing the Boron contents of various tea infusions where the mean total content of boron ranged from8.31 to 18.40mg/kg in black teas, from12.85 to 15.13mg/kg in black tea with fruit flavor, and from12.09 to 22.77mg/kg in fruit brews from different parts of the world such Sri Lanka, Kenya, India, Indonesia etc. Boron is an essential micronutrient. The presence of boron has been demonstrated to favorably affect the function and composition of several body compartments, such as the brain, the skeleton, and also the immune system in humans. Too high concentration of boron in human body may result in nausea, vomiting, diarrhea, and lethargy. The Word Health Organization has announced that a safe range of boron intake for adults is 1–13mg/day (Frankowska *et al*., 2014) [3].

Herbal teas

The most common varieties of herbal teas include mate tea (*Ilex paraguariensis*), hibiscus tea (*Hibiscus sabdariffa*), peppermint tea (*Mentha piperita*) and chamomile tea (*Matricaria recutita*). Herbal teas are actually mixtures of several ingredients, and are more accurately known as ‘tisanes’. Tisanes are made from dried leaves, seeds, grasses, nuts, barks, and fruits, flowers that give them their taste and provide the benefits of herbal teas. (Ravikumar, 2014) [24].
Herbal teas made from Rooibos (*Aspalathus linearis*) and Honeybush (*Cyclopia intermedia*), are used traditionally for medicinal purposes. They are rich in polyphenols with rooibos a rare source of the dietary dihydrochalcones, aspalathin and nothofagin. The predominant polyphenols in honeybush include the xanthone mangiferin and the flavonones hesperitin and isokuranetin. Apart from their divergent phytochemical and nutrient compositions, rooibos and honeybush share potent antioxidant and antimutagenic activities *in vitro* (Mckay & Blumberg, 2007) [17].
The concentration of guaiacol in rooibos was much higher, while linalool was moderately lower and geraniol was absent comparatively with the volatiles in green and black tea. Several phenolic compounds were present in the brewed teas of both green and red rooibos. Significantly higher percentage of total polyphenols (41.2% vs 29.7%), flavonoids (28.1% vs 18.8%) and non-flavonoids (13.1% vs 10.9%) in green

compared with red rooibos were reported. The other predominant flavonoids detected in both types of rooibos tea were rutin (1.3–1.7 mg/g), isoquercetin and hyperoside (0.3–0.4 mg/g), quercetin (0.04–0.11 mg/g), luteolin (0.02–0.03 mg/g) and chrysoeriol (0.01–0.02 mg/g). The presence of the phenolic acids caffeic acid, ferulic acid, p-coumaric acid, p-hydroxybenzoic acid, vanillic acid and protocatechuic acid have been reported in red rooibos tea. Currently rooibos is the only known natural source of aspalathin and one of only two known sources of nothofagin. Rooibos' antioxidant capacity in this assay was also lower than other popular tisanes such as peppermint (0.27 ± 0.02 mg/mL) and hibiscus (0.20 ± 0.02 mg/mL).

Unlike other herbal teas, honeybush is not widely cultivated. The leaves, stems and flowers of the plant are harvested for use in making an herbal tea infusion. In the processed leaves and stems, luteolin, the hydroxycinnamic acid 4-coumaric acid, five isoflanones (formononetin, afrormosin, calycosin, pseudobaptigen and fujikinetin), four flavonones (hesperitin, hesperidin, naringenin, eriodictyol) and three coumestans (medicagol, flemichapparin and sophorocoumestan) were found (Wet, 2015). Aqueous extract of unfermented honeybush had significantly higher total polyphenols (35.3% - 19.8%) and flavonoids (27.1% - 9.9%) compared with an extract of the fermented product. The amount of non-flavonoids was, higher in the fermented than unfermented tea (9.94% - 8.4%, respectively). Du Toit and Joubert (1998) [33] reported that honeybush tea extracts prepared from fermented plant materials containing the flowers had significantly less total polyphenols, but more favorable organoleptic properties including a sweeter aroma, flavor and better quality overall.

Soluble Ethanol/acetone extracts of both unprocessed and processed honeybush teas effectively inhibited lipid peroxidation (63% and 13%, respectively) (Mckay & Blumberg, 2007) [17].McAlpine & Ward, 2016 stated that black and green tea have appreciable quantities of polyphenols and more potent antioxidant capacity than rooibos and herbal teas. Thus steep time correlates to the total pheolic content, longer steep time is not associated with a corresponding higher antioxidant activity.

All the herbal tea extracts showed significant amounts of polyphenols (mg/g) with the highest content in rooibos tea (315) followed by maté tea (151), peppermint tea (93), mallow tea (52) and chamomile tea (50). Correspondingly, remarkable radical scavenging capacity (ARP) was observed in the herbal tea extracts in the order rooibos tea (138) followed by maté tea (113), peppermint tea (118), chamomile tea (19) and mallow tea (12). There appears to be a general correlation of the antioxidant properties of the herbal tea extracts with the content of total polyphenols. Similarly the antioxidant capacity of green teas were significantly higher (Kroyer, 2008) [12].

Mate tea is made up of entirely different polyphenols from those in tea produced from C. *sinensis*. Instead of catechins mate tea has a large concentration of chlorogenic acid, dicaffeoyl quinic acid and xanthines, i.e. caffeine and theobromine. Nonetheless, it possesses a similar antioxidant capacity as green tea. Mate tea is of growing interest in research fields due to its associations to weight loss and possible effects on cancer. Peppermint tea is one of the most popular herbal teas similar to mate teas. The purported benefits include liver disorders, dyspepsia, enteritis, flatulence, gastritis, intestinal colic, and spasms in the bile duct, gallbladder etc (Paquin, 2009) [21]. Being the most popular tisane around the world, Chamomile has different varieties of bioactive compound there are nearly 120 secondary metabolites been identified in chamomile, including 28 terpenoids and 36 flavonoids. Also chamomile tea contains higher levels of apigenin-7-*O*-glucoside, which is one of the most effective bio active agents (Srivastava *et al*, 2010) [29]. Chamomile is one of the most common herbal teas people drink. It has a mild sedative effect, so it's perfect to use as a sleep aid. It relieves stomach pains and acts as a gentle laxative. It helps alleviate menstrual cramps: research indicates that chamomile raises levels of glycine, a substance that calms muscle spasms. (Ravikumar, 2014) [24].

Conclusion

Herbal teas and fruit teas have become popular since the recent years due to their pleasant taste, and exemplary health benefits being effective natural antioxidant sources for food products and as functional dietary food supplements due to their remarkable content of total polyphenols as bioactive substances and significant antoxidant and radical scavenging capacity.

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