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REVIEW PAPER

Production stages, microbiological risk and benefits on health of herbal teas

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Summary

Plants have been used to prepare herbal infusions for centuries. Production of herbal tea consists of several steps, beginning with harvesting, cleaning form residues, drying, storage of herb in a suitable material, grinding, and blending. Te plants grow in different regions and climatic conditions, varying by their physical properties. They are consumed for different purposes and due to their chemical constituents. Many of them have therapeutic effects. Besides their various benefits and even antimicrobial effects, they also carry some microorganisms. Thus, the botanical characteristics and effects on the health of frequently consumed herbal teas and recommendations on their consumption with considered microbial risks are reviewed in this article.

Key words: ***herbal tea, health, contamination, antioxidant***

Słowa kluczowe: ***herbata ziołowa, zdrowie, zanieczyszczenie, działanie antyoksydacyjne***

INTRODUCTION

Fresh or dried fruits, leaves, flowers, roots, seeds or stems are collected and then infused or macerated in order to prepare for consumption, usually just before use. Roots, rhizomes, and crustaceans are used for boiling or maceration, while leaves, flowers, and sensitive parts are usually suitable for infusion. Thus, tea might be macerated by soaking the herb material at a room temperature for ~30 minutes and infusion can be prepared by pouring herbal tea with boiling water and held for ~5–15 minutes [1, 2].

For ages, plant material and herbal teas have been used in the treatment of many diseases. The World Health Organization (WHO) states that about 4 billion people have tried herbal products as first in health problems [3]. As a result of this interest in herbs, tea consumption worldwide also increased annually by 4.5 percent to 5.5 million tonnes over the decade to 2016 [4]. According to a study of tea consumption statistics made in 2013, in Turkey lime tea was the most frequently consumed herbal tea (59.1%), which was followed by sage tea, rosehip, green tea, mint-lemon tea, chamomile tea, mint tea, blackberry tea, lemon tea, apple tea, cinnamon-cloves tea, and others [5].

The composition of soil, distance to equator, and altitude of the region where the plant grows affects the yield of harvest. The width and size of the tea leaves vary according to the amount of water taken from the soil. This can change the characteristics of herbal teas. Variation in tea products is not only because of different raw material but also because of the difference in the process. Some procedures require only drying (e.g. in white tea production), whereas sometimes additional processes such as steaming, rolling, drying and fermentation [6].

STAGES OF HERBAL TEA PRODUCTION

The first stage of production of herbal tea is harvesting at the appropriate time depending on the part of herb. Aboveground parts of herbaceous plant should be piled up at the beginning of flowering and at the end of vegetation. The leaves should be collected before flowering, and underground parts and stem collected before drying, whereas fruits should be collected after maturation [7].

The next step is the removal of dirt. This process can be performed manually or mechanically. Thereafter, drying (in 80°C) is carried out either under the sunlight or under the shade or *via* hot air assisted method. In this phase, the target is to reach the lowest water content (<0.40) fast and without loss of material. This process minimizes mold and causes insect damage on the product, thus herb can be stored for a long time. However, a suitable contact material is important to establish cool, non-humid, and dark environment for safe storage [7].

Then, a grinding stage is applied to obtain smaller particles. At this stage, achieving the appropriate grinding degree is essential to prevent a blurry infusion. On the other hand, the material used for storage also affects grinding degree of herbal tea. As a last stage, blending is performed to obtaind different herbal tea mixture. Supplementation of vitamin-mineral or sweetener can be done according to the products' features [7, 8].

FREQUENTLY CONSUMED HERBAL TEAS

Linden tea (*Tilia cordata* Miller*, Tilia platyphyllos* Scop.)

The linden plant is a tree from the *Tiliaceae* family. Its species are used for different purposes, such as *Tilia cordata* and *Tilia platyphyllos* are preferred due to their therapeutic effects, and *Tilia vulgaris* is consumed as an herbal tea [9]. It grows in Europe, North America, China, and as well as in Northern Turkey [10].

This plant contains various types of flavonoids (quercetin, isoquercitrin, astragalin, hyperoside, rutin, tyloside, quercetin-3,7-O-α-L-diramnoside, camphorol-3,7-O-α-L-diramnoside), condensed tannins (procyanidin B2), essential oils (linalool, geraniol, geranyl acetate, farnesol, farnesilacetate, 1,8-cineol, 2-phenyl alcohol, phenyl-ethyl benzoate, alkanes), mucilages (uronic acids), phenolic acids (caffeic acid, *p*-coumaric acid, chlorogenic acid) and amino acids in its chemical structure [11].

Its flowers' benefits for health such as antispasmodic, diaphoretic, hypotensive, diuretic, tranquilizing, anticonvulsant, analgesic, and chest softening are well-known. Linden tea is used especially against cold and cough, as a sedative and diuretic [12, 13]. These effects of linden tea originate from flavonoids, mucilages, and oils [9, 14]. Although there is no available report on its side effect, its usage for longer time than 2 months is not recommended [10].

Sage tea (*Salvia officinalis* L.)

Sage (*Salvia officinalis* L., *Salvia triloba* L.) belongs to the *Lamiaceae* family. It is a perennial plant with 50–100 cm height, purplish-blue flowers, simple leaf. The wild type of this plant is found in Central Europe and Western Balkans. It is also cultured in Turkey. Its leaves, flowers, and essential oils are used for various purposes [15, 16]. The genus *Salvia* (*Lamiaceae*) spread throughout the world (nearly 900 species worldwide). Only in Turkey this genus has 89 species with a total of 94 taxa, of which 45 are endemic in Turkey [15]. Additionally, *Salvia tomentose*, a large flowering sage species that grows especially in high regions of coastal areas, is grown in Turkey and its leaves are consumed as a tea. Sage has fringe roots with a length ranging from 60 cm to 100 cm [17]. Dried leaves of *Salvia* *fruticosa* (*Salvia triloba*) is a commonly consumed tea in Turkey [16, 17].

The chemical structure of this plant contains several essential oils (*α*- and *β*-thuyene, camphor, cineol, borneol), tannins, and bitter substances. It contains various flavonoids and phenolic compounds (5-methoxysalvigenin, apigenin, hispidulin, cirimaritin). Carnosol, carnosic acid, rosmadial, rosmanol, epirosmanol, and methyl carnosate are the most important phenolic components. Caffeic acid (sagecoumarin), polysaccharides, and some estrogenic substances are also included [15, 16].

Sage is an aromatic herb with antioxidant activity, which reduces lipid oxidation. The total antioxidant activity of sage is higher than *α*-tocopherol [18]. This herb has also antidiabetic properties. Sage may inhibit gluconeogenesis or glycogenolysis in the liver, by its fasting glucose-reducing effect [19]. Sage also has various pharmacological effects such as the increase of pain tolerance, analgesic, and anti-inflammatory activity [20].

White, green, oolong, and black tea (*Camellia sinensis*)

Camellia sinensis belongs to the *Theaceae* family, which is an evergreen tea. Plant leaves of *Camellia sinensis* are used for tea production through different methods. Differences between the processes lead to the formation of different tea species; i.e. black tea, green tea, and oolong tea. White tea is produced by drying process. Japanese style green tea is produced by steaming, rolling, and drying, whereas Chinese style green tea is produced by withering, pan firing, rolling/shaping, and drying. Oolong tea is produced by solar withering rolling, semi fermentation, and tray drying. Black tea is produced by withering, rolling, fermentation, and tray drying of *Camellia sinensis* [6]. In a study, tea was found as a most frequently consumed beverage after water and 20–28.8% of total tea consumption was green tea in Turkey [5, 21].

Tea production started in China and reached Europe through the Arabian tribes. In nature, it grows up to 10–15 m in height, but cultivates of this tree are shorter. Its leaves are short, light green, crustacean, and about 4 cm wide. Young leaves are pubescent, mature leaves are bright green coloured, skinny and smooth. The flowers are white, fragrant, 2.5–4 cm in diameter. Today tea is produced mostly in India, South Russia, East Africa, Java, Sri Lanka, Sumatra, Argentina, and Turkey [22].

At the beginning of 8th century, green tea was transported from China to Japan. Thereafter, green tea consumption began to spread throughout the world. Its unique flavour and smell put it among the most commonly consumed beverages. Some proteins and carbohydrates contain sources of fiber in the water-insoluble form of the leaves of green tea leaves. If the tea leaves contact with hot water, only the components with small molecular weight can pass into the water [23]. Polyphenols (flavonols, hydroxyl-4-flavanols, anthocyanins, flavones, flavonols and phenolic acids (gallic, caffeic, and chlorogenic acids) constitute its 25-35% of the dry weight [23]. Especially, kaempferol, myricetin and quercetin from flavonols; catechins ((±)-epicatechin (EC), (-)-epicatechin gallate (ECG), (±)-epigallocatechin (EGC) and (-)-epigallocatechin gallate (EGCG)) from flavans are found abundantly in the structure of green tea [24]. Caffein is also mentioned as a green tea component. After a 5-minute infusion process, the amount of caffeine in the green tea leaves was determined as 0.086–2.23 mg/g [25].

Camellia sinensis has a high antioxidant properties regarding its phenolic components and some vitamins in its structure. The fermentation process affects its components as well. Therefore, the unfermented sort of tea, i.e. green tea, has more antioxidant properties than black tea and oolong tea [26]. Free radical scavengers green tea help protect cardiovascular system health, has anti-aging activity, and prevent cancer cells' formation [27, 28]. It is known that polysaccharides, polyphenols, and caffeine found in green tea are effective for increasing the metabolic rate and prevention from obesity and adipose tissue formation [29].

Chamomile tea (*Matricaria chamomilla*)

The chamomile *(Matricaria chamomilla* L.*)* in *Asteraceae* family is one of the most important medicinal plants of Southern and Eastern Europe. It is endemic in Europe, e.g. Germany, Hungary, France, Russia, former Yugoslavia areas, North-West Asia, North America, and in Brazil. It also grows near to roads in Turkey. Hungary is the primary producer of chamomile and this plant is a good income source for people of the region [30, 31]. Chamomile is a seasonal plant, with fine spindle-shaped roots. It grows up to 10–80 cm and has long and narrow leaves. Its threaded yellow tubular flowers are 1.5–2.5 mm long, white plant flowers are 6–11 mm long [31].

M. chamomilla belongs to a large group of medicinal plants. Its active compounds have promoted its therapeutic use. The most important bioactive components it contains are sesquiterpenes, flavonoids, coumarins, and polyacetylenes. (Z)- and (E)-2 β-d-glucopyranosyloxy-4-methoxycinnamic acid (GMCA), the precursor of glucoside herniarin, glucagon, luteolin, and luteolin-7-0-glucoside (flavons), quercetin and rutin (flavonols) and naringenin (flavanone), herniarin and umbelliferone (coumarin), chlorogenic acid and caffeic acid (phenylpropanoids), apigenin [31]. It also contains essential oils such as bisabolol oxide A, α-bisabolol, bisabolol oxide B, cis-enyne-bicycloether, bisabolol oxide, chamazulene, spathulenol, and (E)-β-farnesene [32].

Antimicrobial, antifungal, anticancer, antimutagenic, antidiabetic, antiviral, antiinflammatory, and antiprotozoal activities are determined in the essential oils of chamomile. Its phenolic compounds have antioxidant properties, which provide a cellular damage-inhibiting effect caused by free radicals [33, 34]. The apigenin found in the structure of chamomile has a pronounced affinity at the benzodiazepine receptors. This explains the mechanism of a sedative effect. It also significantly reduces the severity of hot flashes in postmenopausal women, alleviating sleep disturbances, and fatigue [35, 36]. By-products may be generated related to the high consumption of the leaves of *M. chamomille*, which may cause allergic reactions due to the photoactivation of the coumarins [37].

Fennel tea (*Foeniculum vulgare*)

Foeniculum vulgare, a family of *Umbelliferae* (*Apiaceae*), is a delicious medicinal plant used by humans since antiquity. It grows naturally in the Mediterranean region and Europe, Asia, North Africa, South America. *F. vulgare* is a vertical, perennial plant that grows up to 2 meters and has soft, hairy leaves. It has a large number of branched with smooth, polished, and bright green leaves. Its leaves grow up to 40 cm long and have a final section like a filiform about 0.5 mm wide. Its flowers bloom in July and August [38, 39].

F. vulgare is a plant that is widely grown and rich in minerals such as potassium, sodium, phosphorus, and calcium. Leaves and stems have the highest moisture content (76.36 and 77.46 g/100 g) and flowers have the lowest moisture content (71.31 g/100 g). Carbohydrates are the main macronutrient in all parts of the plant, ranging from 18.44 to 22.82 g/100 g. Proteins are 1.08 g/100 g in the stalk and 1.37 g/100 g in the flower buds. 100 grams of the plant contains 0.63 g of leucine, 0.73 g of isoleucine, 0.45 g of phenylalanine, 0.53 g of tryptophan. It includes approximately 0.55 g glycine and 0.53 g proline. Phenolic compounds are important for fruit quality because they affect the taste, color, and nutritional properties of the fruit. Fennel's phenolic compounds contain neochlorogenic acid, chlorogenic acid, gallic acid, caffeic acid, *p*-coumaric acid, ferulic acid-7-0-glucoside, quercetin-7-0-glucoside, ferulic acid, 1,5-cinnamic acid, rosmarinic acid, quercetin, and apigenin [40, 41].

Fennel is an important substance for polyherbal formulations in the treatment of different diseases and disorders. Several essential oils and phenolic compounds of *F. vulgare* has health-promoting effects such as antiaging, antiallergic, anticholitic, antihirsutism, anti-inflammatory, antimicrobial, antiviral, antimutagenic, antinociceptive, antipyretic, antispasmodic, anxiolytic, apoptotic, antitumor, diuretic, galactogenic, preservative, cytochrome P450 3A4 enzyme system inhibitor, hypoglycemic, hypolipidemic activities, estrogenic, and expectorant [42-44].

Senna tea (*Cassia acutifolia, Cassia angustifolia*)

Cassia sp. belongs to the *Fabaceae* (*Leguminosae*) family and grows in India and other tropical regions. The plant needs a temperature higher than 10°C to grow and humidity similar to coastal areas, riverbanks, waste areas, and a 1000–1400 m height of altitude. *Cassia* species are wild plants, with a 30–90 cm high, and have 6–8 cm long, green, needle year-round leaves. Its flowers usually have five pale yellow leaves [31].

O-β-D-glucopyranoside, an amorphous light yellow substance, kaempferol-3-O-gentiobioside in a yellow crystal form, and 1,7-dihydroxy-3-carboxyanthraquinone sinamycin in an orange crystal form are three main compounds of senna tea. 3-O-gentiobiose kaempferol is a flavonoid that occurs in this plant [45]. The senna leaves carry anthracene derivatives at rates of 2.5–3.5%. It contains chrysophanol, aloe-emodin, and mucilage [46].

Cassia species has various benefits for health such as antitumor, anthelmintic, antibacterial, antioxidant, anti-inflammatory, and antidiabetic effects. However, it has healing effects on obesity and hepatic lipogenesis [47-51]. Cinnamon leaf has also a laxative effect, however, its long-term use results in severe electrolyte losses [52].

Ginger (*Zingiber officinale*)

Ginger belongs to the family *Zingiberaceae* and one of the most important and common spices in the world. It has spread to many tropical and subtropical countries from the Sino-Indian region. In ancient times, ginger played an important role in primary health care in India and China. Ginger is used as a pharmaceutical in European medicine. It has thin, short (rarely 50 cm in length), sticky, or fairly short leaves. It can reach up to 150 cm in height [53].

Oleoresin and total essence of ginger are responsible for ginger flavour. Gingerol and shogaol are two important compounds in the structure of oleoresin, which contribute to the ginger flavor. In long-term storage, ginger converts to shogaol. The quality of ginger depends on the relative content of gingerol and shogaol. Its essential oils are composed of 20–25% of oleoresins (camphor, β-phelandrene, 1,8-cineole, geranial, and neral) and additionally, it contains also sesquiterpenes. Gingerols, shogaols, and their phenol ketone derivatives are bitter compounds for the building of these essential oils [53, 54].

Ginger is an effective plant in prevention of vomiting and bulimia. It also has a lowering effect on insulin resistance in individuals with type 2 diabetes. Antioxidative and anti-inflammatory effects protect cells against the damage of free radicals and have positive effects on cardiovascular health [55-58].

Mate tea (*Ilex paraguariensis*)

The tea was obtained by drying the leaves of the *Ilex paraguariensis* plant from the *Aquifoliaceae* family is frequently consumed in the south Latin American countries. Mate grows endemically in southern regions of South America (Brazil, Argentina, Paraguay, Uruguay). In recent years, it has spread rapidly into the world market. It can reach to 18 m height, is a leafless, long-lasting plant. It grows in regions with high precipitation and at an average annual temperature of 21–22°C, which can withstand up to –6°C [59].

The chemical structure of mate is rich in polyphenols, which mainly consist of chlorogenic acid (92 mg equivalents per gram in its dry leaf). In blended teas, the amount of this component is considerably reduced [60]. Mate is a source of methylxanthines and also consists of theophylline (1,3-dimethylxanthine), theobromine (3,7-dimethylxanthine) and caffeine (1,3,7-trimethylxanthine). Among these components, caffeine has the highest concentrations (1-2% of dry weight). This is followed by theobromine, which is present as 0.3–0.9% in its dry weight. In a cup of mate tea (~150 ml) 78 mg caffeine content is estimated [61, 62]. Caffeoyl derivatives of mate include caffeic acid, chlorogenic acid, 3,4-dicaffeoylquinic acid, 3,5-dicapoylquinic acid, and 4,5-dicapoylicinic acid [63]. Saponins are also present in flavor compounds in mate tea [59].

The caffeoyl derivatives of mate tea contain routine, tannin, and ursolic acid as the main constituents of its antioxidant capacity. Caffeine has anticancerogenic, antiobesity, antioxidant, antitumoral, diuretic, energizing, stimulant, topoisomerase-1 inhibitor effects [64, 65]. It is proven that mate tea gives positive results on obesity and weight management [65]. Cytotoxicity studies showed an anti-cancer activity by providing TPA-stimulated ornithine decarboxylase, quinone reductase activities through HepG2 cells, and topoisomerase inhibition by using *Saccharomyces cerevisiae* [67]. Several frequently consumed herbal teas regarding their chemical composition and purpose of usage are presented in table 1.

MICROBIAL RISKS

Dried herbs can be contaminated with pathogens at any point in the production chains (cultivation, harvesting, processing, packaging, storage, and marketing). Contamination of soil and irrigation water, animal-borne contaminants, and contaminations from field workers may cause the growth of fungi or bacteria. Microorganisms can be transferred to the leaves from the hands or harvesting equipment during the production (cultivation) or harvesting. Omagbai *et al.* [68] found several fungi (*Aspergillus niger, Aspergillus flavus, Penicillum expansum, Rhizopus stolonifer, Fusarium solanii*) and bacteria (*Staphylococcus aureus, Staphylococcus epidermidis, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, Klebsiella pneumonia, Serratia marcencens, Salmonella typhimurium, Pseudomonas fluorescens*) on the herbal teas in their microbiologically study. The bacterial content of herbal teas varied between 1.1 x 10^1 and 3.6 x 10^2 colony forming unit (cfu)/g, whereas the fungal content varied between 1.3 x 10^2 and 4.5 x 10^5 cfu/g in their study [68]. In another study by Tournas and Katsoudas [69], the mold-yeast content of different tea types was studied and the mold-yeast contamination rate was up to 1.4 x 10^5 cfu/g. All

Table 1.

Bioactive compounds and the effects of herbal teas

Herbal tea	Family	Compounds		Purpose of usage	References
Linden tea (*Tilia* sp.)	*Tiliaceae*	quercetin isoquercitrin astragalin hyperoside rutin tyloside camphorol procyanidin linalool	geraniol geranyl acetate farnesol farnesilacetate 1,8-cineol 2-phenyl alcohol phenyl-ethyl benzoate alkanes	antispasmodic diaphoretic hypotensive diuretic tranquilizing anticonvulsant analgesic chest softening	[9, 11-13]
Sage tea (*Salvia* sp.)	*Lamiaceae*	5-methoxysalvigenin apigenin hispidulin sirimaritin	camphor cineol borneol	antioxidant antidiabetic pain tolerance analgesic anti-inflammatory	[15, 16, 18, 20]
White, Green, Oolong, Black Tea (*Camellia sinensis*)	*Theaceae*	kaempferol mycerin quercetin catechins epicatechin	epicatechin gallate epigallocatechin epigallocatechin gallate caffeine theophylline theobromine	stimulates the central nervous system antioxidant diuretic antibacterial	[6, 23, 29, 61]
Chamomile tea (*Matricaria chamomilla*)	*Asteraceae*	luteolin quercetin rutin naringenin herniarin umbelliferone	chlorogenic acid caffeic acid apigenin bisabolol oxides bicycloether, spathulenol (e)-β-farnesene	antimicrobial antifungal anticancer antimutagenic antidiabetic antiviral antiinflamatuar	[30-34]
Fennel tea	*Umbelliferae*	neochlorogenic acid chlorogenic acid allic acid caffeic acid coumaric acid	ferulic acid quercetin cinnamic acid rosmarinic acid apigenin	antiaging antiallergic anticholitic anti-inflammatory antimicrobial antimutagenic antispasmodic hypolipidemic	[38-41, 43, 44, 68]
Senna tea (*Cassia* sp.)	*Fabaceae*	anthraquinone aloe-emadins chrysophanol		antitumor anthelmintic antibacterial antioxidant anti-inflammatory antidiabetic	[31, 47-51]
Ginger tea (*Zingiber officinale*)	*Zingiberaceae*	Ooleoresin sesquiterpenes gingerols shogaols		antiemetic antioxidative anti-inflammatory	[53-58]
Mate tea (*Ilex paraguariensis)*	*Aquifoliaceae*	chlorogenic acid theophylline theobromine caffeine tannin ursolic acid	caffeic acid chlorogenic acid 3,4-dicaffeoylquinic acid 3,5-dicapoylquinic acid 4,5-dicapoylicinic acid	anticancerogenic antiobesity antioxidant antitumoral diuretic energizing stimulant	[59, 60, 63, 64]

of the herbal teas analyzed in the same study were found to be contaminated with mesophilic aerobic bacteria (MAB, minimum 1.6 x 10^3, maximum 1.2 x 10^7 cfu/g [68]. In the study of Vidović *et al.* [70], 67% of the herb samples had a MAB content higher than 10^6 cfu/g and a significant increase in MAB content was detected during the processing of raw materials. In the same study, mold and yeast content were noted between 3.13 and 4.41 $\log_{10}$ cfu/g [70].

It is important to minimize the microbial content with the correct heat treatments without loss of healthy effects of the tea. Temperatures above 80°C significantly reduce microbial loads on tea leaves. However, fungi such as *Aspergillus* can grow in low water activities, care must be taken to dry the product quickly to prevent such growth and possible production of toxic metabolites [71, 72]. Particularly mycotoxins the secondary metabolites of fungi and several heat resistant bacterial pathogens, such as *Cronobacter sakazakii*, can cause a decrease in the beneficial effect of herbal tea on health.

CONCLUSIONS

Herbal teas are commonly consumed in most countries. Many studies proved their health benefits. However, there is still lack of knowledge on their safe consumption levels. In addition, due to their allergic potential and other unexpected results, pregnant and lactating women and people with specific illnesses should consult a doctor before consuming herbal teas. Therefore, it seems that predictive studies are needed to investigate its usage, particularly in susceptible populations and assessment of the potential risks and benefits. Especially risk assessment approaches can be combined with consumption habits in order to estimate the exposure to toxicological and/or microbial hazards of herbs.

Ethical approval: The conducted research is not related to either human or animal use.

Conflict of interest: Authors declare no conflict of interest.

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