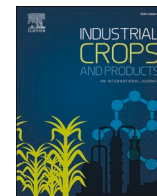




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Tea and coffee polyphenols and their biological properties based on the latest *in vitro* investigations

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ABSTRACT

Tea and coffee contain numerous polyphenolic compounds that exhibit health-promoting properties for humans, including antioxidant and neuroprotective properties, and can also take part in the treatment of covid-19 and improve fertility. This review, presents the activity of polyphenols found in different types of tea and coffee and describes the effects of tea fermentation and coffee roasting on their polyphenol composition and antioxidant properties. Polyphenol oxidase activity is reduced in the fermentation process; therefore black tea contains significantly less polyphenolic compounds compared to green and white tea. Epigallocatechin-3-gallate - a polyphenol from tea - effectively has been shown to inhibit the activity of SARS-CoV-2 as it blocked binding of coronavirus 2 to human angiotensin converting enzyme 2, decreased the expression of inflammatory factors in the blood, including tumor necrosis factor- α and interleukin-6, and significantly increased the overall fertilization efficiency in animals. Coffee roasting process influences both the content of polyphenols and the oxidative activity. The lowest levels of active compounds such as caffeine, chlorogenic acid and coffee acids are identified in roasted coffee beans. On the other hand, light coffee and green coffee show the strongest cytotoxic potential and antioxidant properties, and thus the greatest ability to decrease apoptosis by stopping the cell cycle in the S phase. Proteins, such as components of milk, can strongly bind/interact with phenolic compounds (especially, the CGAs) contain in coffee, which may explain the negative influence of milk on its antioxidant properties. Coffee polyphenols have also antiproliferative and antiesterase activities, which may be important in prevention of cancer and neurodegenerative disorders, respectively. In this review, biological properties of tea and coffee polyphenols, observed mainly in *in vitro* studies have been described. Based on these findings, future directions of the research works on these compounds have been suggested.

1. Introduction

Drinking tea or coffee has become one of the most popular traditions today Internationally. Tea has won a place of honour in society and has become one of the most versatile drinks for everyone. Generally, there are 3 types of tea that differ in the degree of fermentation: unfermented green and white tea, partially fermented oolong tea and fully fermented black tea (Chan et al., 2011). Coffee is divided into 2 types - ground coffee and instant coffee. Teas have a different composition, which results, among others, from the geological location, the method of cultivation and treatment of the obtained leaves. Production of green tea involves steaming of its leaves to limit oxidation and inactivate polyphenol oxidase, followed by drying the leaves. In turn, to produce black tea, leaves are strongly oxidized for about 100 min whereas, oolong tea

undergoes a shorter fermentation than black tea. White tea is made of younger leaves of tea, which are harvested once a year, then, right after harvesting, the leaves are steamed and then dried (Fig. 1).

White tea (WT) contains the highest level of phenolic compounds and is the least processed tea, as well as one of the less studied (Dias et al., 2013). The biological properties of tea and coffee are related to the content of polyphenols (flavonoids, catechins, tannins) caffeine, etc. The scavenging of free radicals by these compounds gives tea and coffee strong antioxidant properties as observed in *in vitro* and *in vivo* studies (Wiseman et al., 1997).

Polyphenol oxidase in tea is a thermolabile enzyme. The activity of polyphenol oxidase is reduced by heating during the fermentation process; therefore white and green teas not fully fermented contain more polyphenols and have better ability to scavenge reactive forms of oxygen

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than black tea.

Polyphenols contained in tea can be used in the prevention and control of diseases by removing reactive oxygen species and regulating the activity of oxidases in the body. These abilities are related to the hydroxyl structure, which has the capability of binding of hydrogen ions and that scavenges free radicals (Zhou et al., 2018). Moreover, polyphenols and other compounds from original and specific Chinese herbal *Rhodobryum ontariense* moss tea have antibacterial (against all investigated bacteria) and antifungal properties, mainly against *Candida albicans*. This may indicate that *R. ontariense* tea is a good candidate in the searching for new agents against *C. albicans* (Boris et al., 2013).

On the other hand, coffee, apart from the presence of caffeine, contains numerous bioactive compounds, including those having antioxidant properties, e.g. phenolic acids belonging to the hydroxycinnamic acid family (caffeic, chlorogenic, p-coumaric and ferulic acids). Multiple studies have reported the presence of phenolic acids in green coffee (chlorogenic acid) or roasted coffee (other phenolic acids), while only a few studies have focused on the content of flavonoids in the final product (Lee et al., 2016). Active compounds contained in coffee take part in various biological processes, as they exhibit chemoprotective effect, antioxidant and anti-inflammatory properties, and anticancer activity (Soares et al., 2018). Drinking coffee can protect against cardiovascular disease, obesity, some types of cancer and type 2 diabetes (Gökçen and Şanlıer, 2017; Hu et al., 2018).

2. Definition and classification of tea and coffee phenols

2.1. Tea phenols

Polyphenols found in tea are called catechins, the content of which in the dry matter of brewed green tea is 30–42%. These compounds are characterized by a di- or tri-hydroxyl substituents in the ring B and a meta-5,7-dihydroxy substituents in the ring A (Khan and Mukhtar, 2007). The most important of tea polyphenols are classified into the 4 types: epigallocatechin-3-gallate (EGCG), epicatechin-3-gallate (ECG), epigallocatechin (EGC) and epicatechin (EC). Catechins are made up of 3 hydrocarbon rings and are structurally divided into estrocatechins

(EGCG, ECG) and non-ester catechins (EGC, EC). According to the resistance to oxidation, catechins can be sorted:: EGCG > EGC > ECG > Gallic acid (GA) (Ravindranath et al., 2007). The antioxidant properties are determined by the position of the hydroxyl groups and their number in the structure of these compounds. As such, catechins are strong hydrogen suppliers on B and C rings, whereas the 2, 3- double bond and the unsaturated 4-oxo group in the C-ring promote electron delocalization (free electron) of the ortho-dihydroxy catechol in the B-ring (Khan and Mukhtar, 2007). In addition, the conditions of the reaction environment and the starting conditions are responsible for the antioxidant activity of these compounds (Zhou et al., 2005; Dai et al., 2008) (Fig. 2).

Catechins undergo extensive biotransformation including methylation, glucuronidation, sulfation and ring cleavage metabolism. Research on the enzymology of EGC and EGCG methylation showed that EGC is methylated to 4'-O-methyl(-)-EGC and EGCG is methylated to 4'-O-methyl(-)-EGCG and 4',4'-O-dimethyl(-)-EGCG. In research of EGCG and EGC glucuronidation, it has been reported that EGCG-4'-O-glucuronide is the major metabolite formed by human, mouse and rat microsomes (Lambert and Yang, 2003; Lambert and Yang, 2003a). Flavonols are also present in tea, including quercetin, kaempferol, myricetin and their glycosides. A typical tea drink, prepared at the rate of 1 g of leaf per 100 mL of water for a 3-min infusion, usually contains 250–350 mg of dry weight tea, consisting of 30–42% catechins and 3–6% caffeine (Mukhtar and Ahmad, 1999). According to the tea production process, white tea contains relatively low concentrations of tea flavins and arubigins and high concentrations of catechins. The degree of tea processing influences the tea flavonol content (Dias et al., 2013). Đorđević et al. (2018) assessed the antioxidant activity of polyphenols present in wines and showed that higher content of catechin and gallic acid in the product led to its stronger antioxidant activity and increased survival of yeast cells exposed to oxidative stress. The overall concentration of polyphenols, total catechins, gallic acid, theobromine, EGC, ECG and EGCG are significantly lower in green tea compared to white tea (Hilal and Engelhardt, 2007; Santana-Rios et al., 2001).

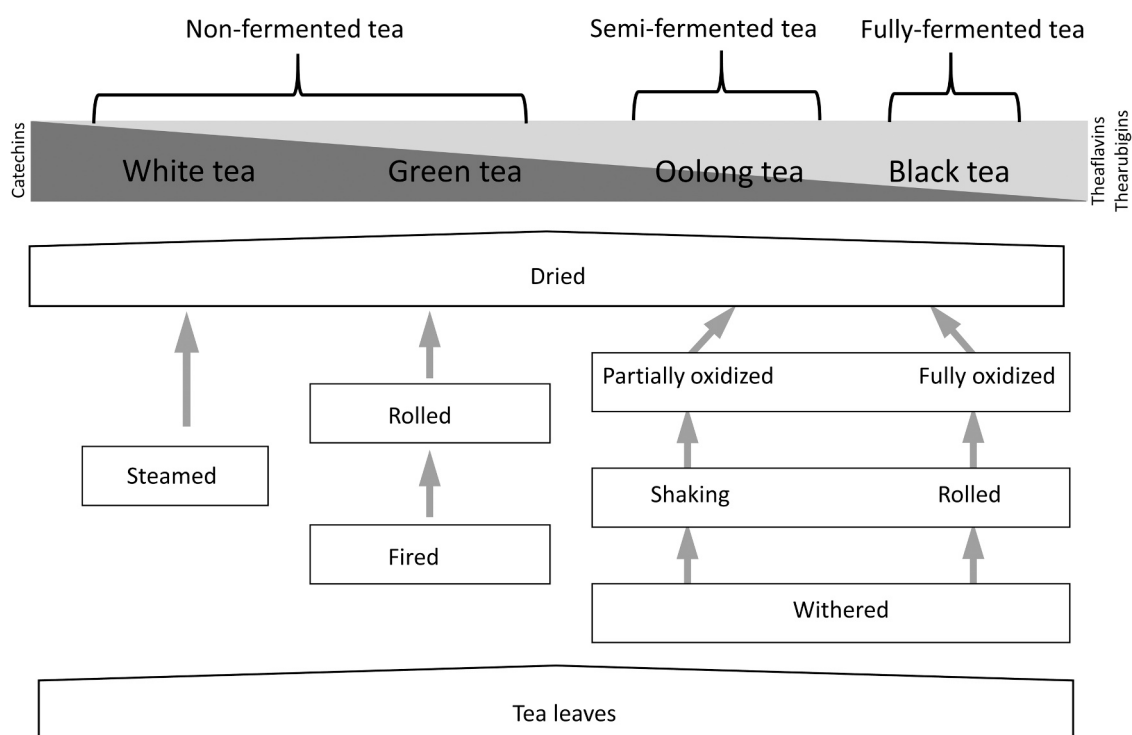


Fig. 1. Tea productions scheme.

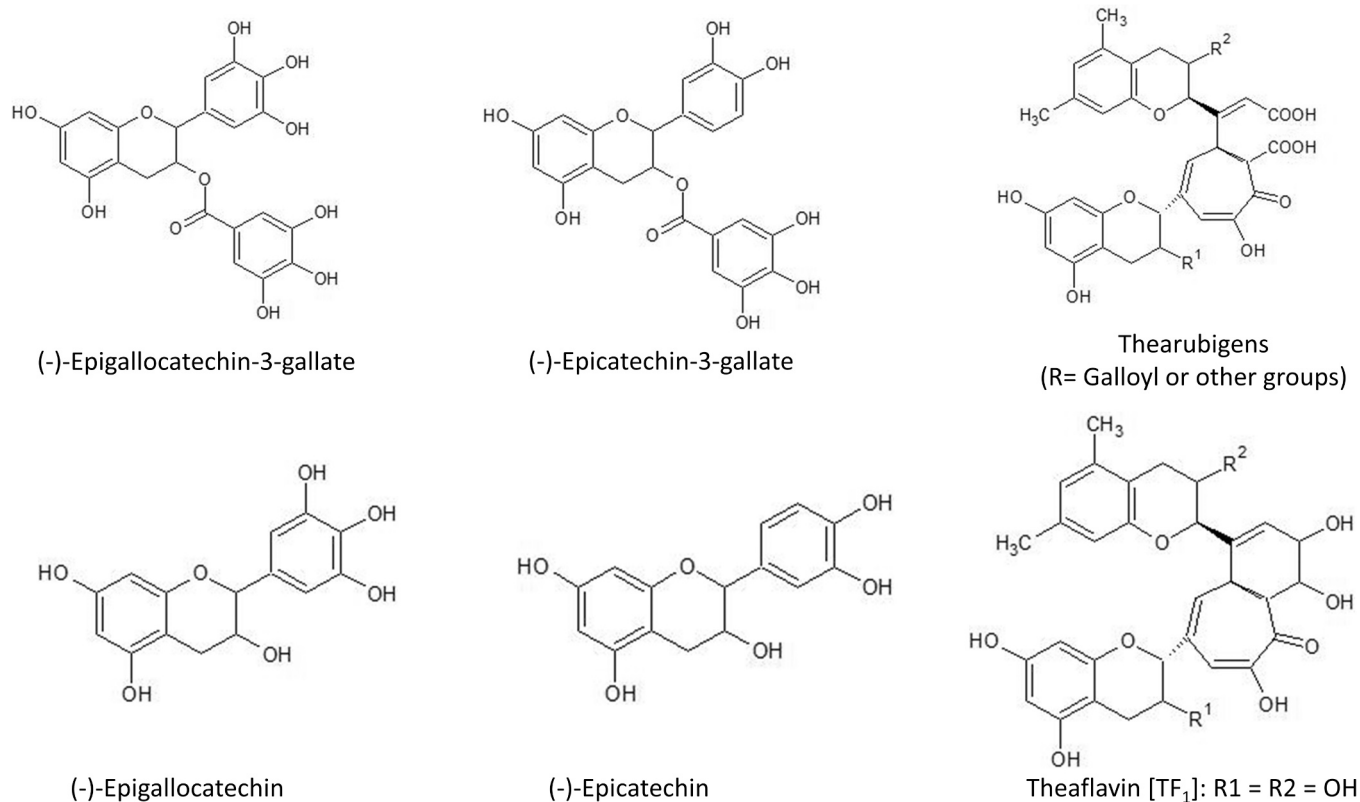


Fig. 2. Chemical structures of tea polyphenols.

2.2. Coffee phenols

Coffee composition is complex, but the main ingredients are caffeine, diterpene, kahweol and chlorogenic acid, and phenols (Bonita et al., 2007). Typical polyphenols are caffeine, chlorogenic acid, diterpenes and trigonellin (Yesil and Yilmaz, 2013). Main antioxidants present in coffee are chlorogenic acids, caffeine and melanoidins (Santos and Lima, 2016). Chlorogenic acids are a family of esters formed of quinic and coffee acids. Subclasses of chlorogenic acids are: caffeoylquinic (CQA), feruloylquinic (FQA), and dikaoylquinic (diCQA) acids (Santos and Lima, 2016; Stalmach et al., 2010). In roasted coffee beans, melanoidin is produced by non-enzymatic roasting, which is responsible for the antioxidant activity of coffee (Bekedam et al., 2008). Chlorogenic acid content decreases during roasting, while butmelanoidins content increase, which can compensate for the decrease in antioxidant activity of coffee caused by the loss of chlorogenic acid (Fig. 3) (Opitz et al., 2014).

3. Properties of tea polyphenols

3.1. Green tea polyphenols improve fertility

Gadani et al. (2017) examined whether addition of polyphenolic compounds, such as resveratrol (Res) and epigallocatechin-3-gallate (EGCG) to the diluent used to defrost sperm influenced the parameters of sperm quality and *in vitro* fertilization. Res belongs to natural phytoalexins, which are derived from grapes, but among the polyphenols, EGCG found in green tea is considered to be the most important. Sperm cryopreservation is the best effective method ensuring the durability of sperm (Holt, 2000). In the process of cryopreservation, sperm undergoes changes called "cold shock", mainly caused by increasing the ROS level (Wang et al., 1997; Kim et al., 2011), which excessive production leads to sperm damage (Bansal and Bilaspuri, 2011). Gadani et al. (2017) showed that Res or EGCG did not affect acrosome integrity and boar sperm viability, however, they induced a higher penetration rate and significantly increased the overall efficiency of *in vitro* fertilization.

Additionally, Hassan et al. (2019) treated male albino rats with lead acetate (PbAc, 50 mg/L) once a day, which resulted in decreased sperm count and motility, decreased testicular weight, reduced seminal

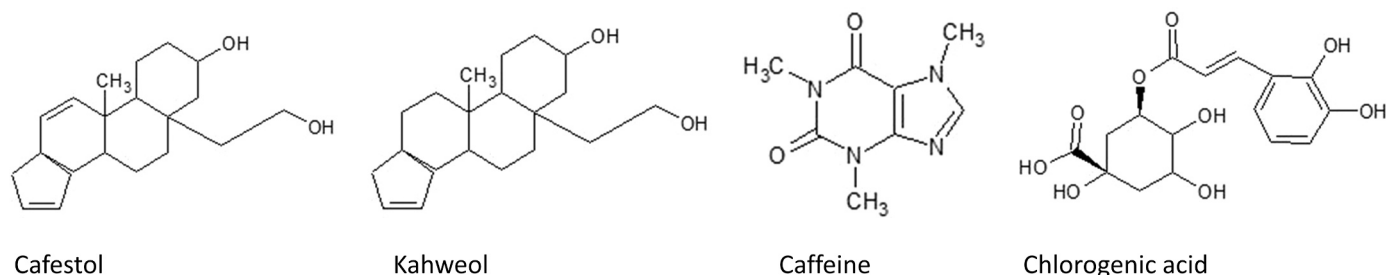


Fig. 3. Chemical structures of bioactive compounds in coffee.

vesicles and epididymis, and low serum testosterone and 17β -estradiol (E2) levels as well as tubular degenerative changes. These undesirable effects were alleviated by treatment with EGCG, which increased testosterone, serum E2 levels, and P450 aromatase gene expression, as well as improved testicular architecture and sperm presentation. Additionally, EGCG lowered the level of lipid peroxidation marker malondialdehyde (MDA) in the tissues and retained the levels of antioxidant enzymes. In conclusion, administration of EGCG can provide significant protection against Pb-induced testicular toxicity, which indicates a beneficial role for epigallocatechin-3-gallate in the male reproductive system (Hassan et al., 2019).

3.2. The possibility of using green and black teas in the treatment of COVID-19

COVID-19 is a viral disease that attacks respiratory epithelial cells and causes inflammation of the mucosa, thus causing damage to the alveoli and eventually pneumonia. Coronaviruses have been reported to cause Severe Acute Respiratory Syndrome (SARS) and Middle East

Respiratory Syndrome (MERS) (Xie and Chen, 2020). Drugs tested in clinical trials include hydroxychloroquine, favipiravir, remdesivir, and lopinavir/ritonavir (Abd El-Aziz and Stockand, 2020). Several other antiviral drugs and new chemical molecules are also being tested for treatment of coronavirus infections.

Several dietary molecules with predetermined antiviral activities are also among the candidates being evaluated for COVID-19 treatment (Mhatre et al., 2021). Jang et al. (2020) checked whether EGCG and theaflavin effectively inhibited the activity of SARS-CoV-2. The main objective in combating the virus is a virus-specific enzymes. Thymidine kinase from herpesvirus is the main target of herpesviral therapies, and thymidine kinase inhibitors, including acyclovir and ganciclovir, have been developed for the treatment of herpetic diseases (Reusser, 1996).

Another coronavirus-specific enzyme, which should be potential target for the drug treatment of coronavirus diseases is 3CL protease responsible for the cleavage of viral polyproteins and required for viral replication (Anand et al., 2003). It has been shown that RNA-encoded viral proteases are essential for the maturation of the coronavirus proteins (Herold et al., 1998). Recently, Jang et al. (2020) showed that

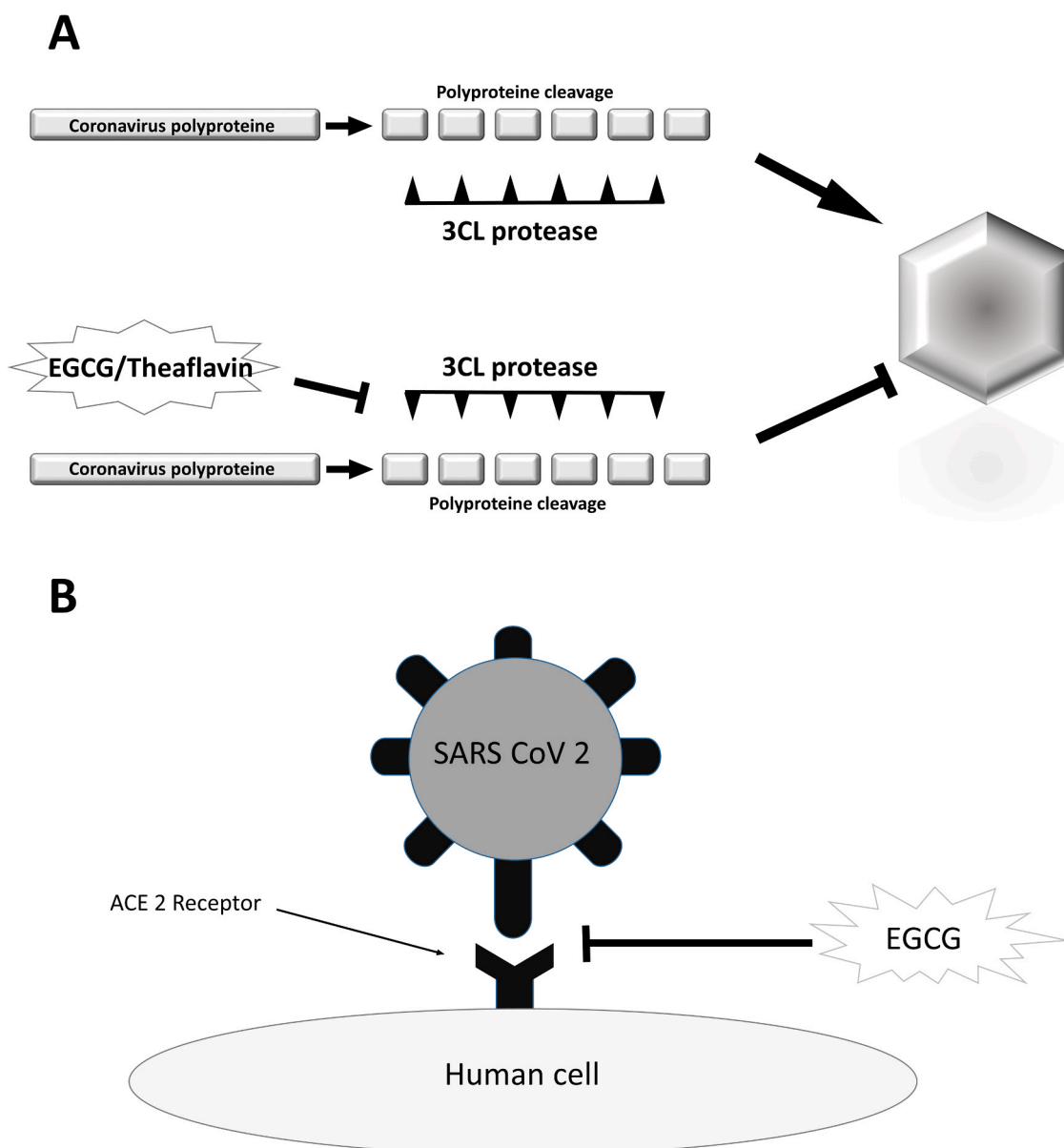


Fig. 4. Antiviral activity of green tea; (A) Antiviral activity of EGCG (Jang et al., 2020); (B) Blocking SARS-CoV-2 binding to human ACE2 receptors (Henss et al., 2021).

EGCG and theaflavin, active ingredients in green tea and black tea, inhibited 3CL proteases. The tests were performed on human embryonic kidney HEK293T cells from cell culture (Fig. 4A). The IC₅₀ concentrations for EGCG and theaflavin were 7.58 µg/mL and 8.44 µg/mL, respectively.

In a recent study, Henss et al. (2021) showed that, EGCG blocked binding of coronavirus 2 (SARS-CoV-2) receptor-binding domain (RBD) to human angiotensin converting enzyme 2 (ACE2) receptors, which could prevent human infection (Fig. 4B). The above mentioned results indicated that EGCG at least partially blocked SARS-CoV-2 entry into target cells. This effect was also seen with worrisome SARS-CoV-2 (VOC) variants. Moreover, EGCG used at viral inhibitory concentrations was not toxic to target cells. However, treating SARS-CoV-2 infection by consuming tea orally does not seem to be a solution to the problem. Consumption of about 500 mL of green tea results in a peak plasma EGCG concentration of < 1 µM, while IC₅₀ value is 3.14 µM. Nevertheless, EGCG has the potential to be used in development of antiviral drugs (Fig. 4B) (Henss et al., 2021).

3.3. Neuroprotective properties

Because the antioxidant activity in the human brain is lower than in other organs, this increases the possibility of high levels of ROS in the brain, in consequence leading to the risk of neurodegenerative diseases such as Alzheimer's and Parkinson's (Mao et al., 2017).

Wei et al. (2016) investigated inhibitory effects of EGCG on microglia activation and amyloid-induced neurotoxicity (Aβ). They showed that EGCG significantly suppressed expression of tumor necrosis factor α (TNFα), interleukin-1β, interleukin-6 and inducible nitric oxide synthase (iNOS) in Aβ-stimulated EOC 13.31. EGCG also restored levels of intracellular antioxidants bound to nuclear factor 2 as well as to heme oxygenase-1 (HO-1). Finally, EGCG inhibited nuclear factor κB (NF-κB)-induced activation of ROS resulting from Aβ treatment.

Zhou et al. (2018) investigated the use of EGCG in the treatment of Parkinson's disease (PD) through its effect on the peripheral immune system in the 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP)-induced PD in mice. Motor deficit mice treated with EGCG showed restoration of their motor behaviour, while EGCG protected TH-positive tyrosine hydroxylase dopaminergic neurons from MPTP toxicity. Moreover, treatment with EGCG lowered the serum expression of inflammatory factors, like tumor necrosis factor-α, and interleukin-6.

In addition, other studies have shown that EGCG inhibited Aβ-induced cytotoxicity by reducing ROS-mediated NF-κB activation and mitogen-activated protein kinase (MAPK) signalling, including c-Jun N-

terminal kinase (JNK) and p38 signalling (Fig. 5) (Cascella et al., 2017).

4. Properties of coffee polyphenols

4.1. Coffee roasting and polyphenols

Coffee has an important bioactive effect, attracting more and more attention, especially, because it is one of the most commonly consumed stimulant drink in the world. As shown by scientific research, standard roasting process of coffee changes its chemical composition. De Souza et al. (2020) investigated the effects of the roasting process on bioactivity of dried extracts of *Coffea arabica* L. They showed a little variation in the amount of the total phenolic content between green coffee and light roast coffee. On the other hand, dark coffee roasting caused an over double reduction in the amount of these compounds, which proved that the content of phenolic compounds decreased with increasing degree of roasting. Moreover, antioxidant activity of green and roasted coffee extracts was analyzed using different scavenging activity methods and almost all of the methods indicated a decrease of antioxidant capacity of coffee beans in the roasting process.

Antioxidant activity of coffee polyphenols is also associated with the potential anticancer effect. De Souza et al. (2020) and Bobková et al. (2020) showed that the roasting process of coffee influenced both the content of polyphenols and its oxidative activity. De Souza et al. (2020) checked the antiproliferative activity of coffee extracts, as well their effect on the cell cycle and apoptosis in the bone (PC-3) and brain (DU-145) metastatic cancer cell lines. The results showed that the lowest levels of caffeine, chlorogenic acids and caffeic acids were observed in dark roasted coffee. Compared to the medium and dark roasted coffee extracts, in PC-3 cells, green and light coffee extracts had higher antioxidant activity as well as promoted cytotoxicity, followed by S-phase cell cycle arrest and induction of apoptosis.

In addition, Król et al. (2019) compared the content of bioactive compounds in organic (ecological) and conventional coffee (*Coffea arabica*). Using high-performance liquid chromatography (HPLC), they indicated that ecological or conventional production and roasting conditions affected coffee polyphenols. The highest content of total polyphenolic compounds was determined in coffee roasted in light and medium roasting conditions. Moreover, organic coffee beans showed a higher content of phenols, phenolic acids and flavonoids than conventional coffee beans. The researchers also assessed the effect of storing coffee in clean bags. Coffee samples stored in vacuum bags at 5 °C for 12 months showed a decrease in the content of polyphenols (Król et al., 2019).

Isac-Torrente et al. (2020) assessed the effects of new ways of coffee brewing - coffee capsules, on antioxidant activity, total phenolics content, concentration of chlorogenic acid, caffeine and melanoidin and compared them with conventional coffee makers. Both caffeinated and decaffeinated coffees were analyzed. They noted that capsule method of roasting coffee showed the lowest values of antioxidant capacity and total phenolics content. Moreover, filter coffee brewed once again showed the high content of polyphenolic compounds, in line with the results reported by Ludwig et al., (2012).

Aluminum (Al) is a toxic metal exerting pro-oxidative, mutagenic and cytotoxic effects in humans (Exley, 2013). Presence of Al in the body seems to trigger a number of health disorders in humans, including cancer (Martinez et al., 2018). As it turns out, the greatest amount of Al is found in decaffeinated coffee. In addition, when coffee is decaffeinated, using the Swiss Water® method and made into capsules, its Al content increases significantly. The appropriate choice of coffee in terms of its roasting and brewing have a significant impact not only on the health-promoting properties of coffee, but also on the content of ingredients harmful to health (Isac-Torrente et al., 2020).

Milek et al. (2021) examined the level of caffeine and antioxidant activity of specialty coffee infusions in comparison to popular coffee brands. As a result of a decreased quality of coffee offered on the market,

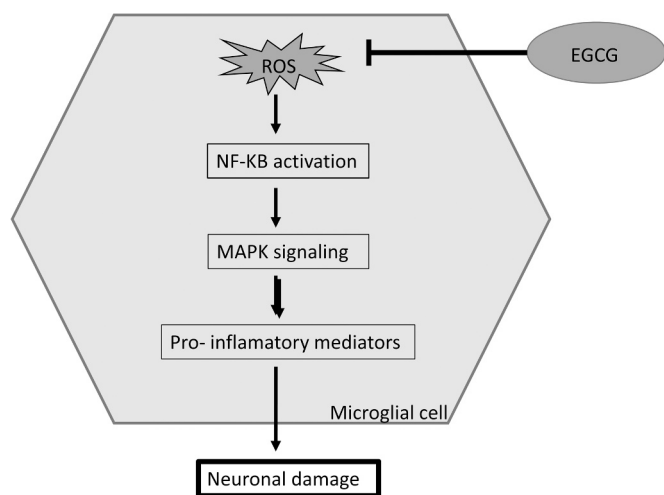


Fig. 5. Neuroprotective properties of EGCG (Mao et al., 2017; Zhou et al., 2018; Cascella et al., 2017).

a type of specialty coffee was born, *i.e.* coffee grown in unique and ideal climates, with a distinctive taste and aroma, practically without defects. Those scientists analyzed seven Arabica specialty coffees, one Robusta and two popular cheap coffee brands. Using HPLC and spectrophotometry, caffeine content in coffee was assessed. Caffeine content in all coffees did not show much difference and its average level was 56 and 40 mg/mL, respectively. Moreover, the antioxidant activity of coffee extracts was assessed. The obtained results showed that specialty coffees had a higher antioxidant activity than popular ones. Specialty coffees showed. Specialty coffees were not better than popular coffees in terms of caffeine content but they exceed them in terms of antioxidant activity. In addition, brewing coffee with a dripper, the so-called overflow method, provided the brew with the best antioxidant properties. Thanks to these results, it is possible to choose coffees with greater awareness of antioxidant properties that may translate into health-promoting properties for consumers (Milek et al., 2021).

Muzykiewicz-Szymańska et al. (2021) analyzed how the antioxidant activity is influenced by water temperature and the roasting time of the beans. Arabica coffees from Brazil, Colombia, India, Peru and Rwanda, both unroasted and roasted beans, were analyzed. The analysis showed that lower antioxidant activity as well as the content of polyphenols, flavonoids and caffeine were obtained in infusions from unroasted coffee compared to freshly ground roasted coffee beans. However, the method of brewing coffee has also a significant impact on its composition and pro-health activity. Coffees prepared using the cold brew method were characterized by a higher content of caffeine and polyphenols in the case of unroasted beans. Hot-brewed coffee extracts showed a higher antioxidant activity and the content of phenolic compounds in the case of roasted beans. However, the time of brewing and water temperature around 90 °C had little effect on coffee properties. It can be concluded that the origin of coffee beans and the applied method of brewing have an impact on the properties of infusions (Muzykiewicz-Szymańska et al., 2021).

Additionally, the results published by Kulapichitr et al., (2022) indicated that heat pump drying at 50 °C is a viable alternative and possibly superior to sun drying for preserving certain desirable chemical and physical characteristics of green coffee. Both process - sun drying and heat pump drying resulted in comparable levels of CGAs and antioxidant activities in green coffees; however, colour parameters, especially lightness, differed.

4.2. Effect of adding milk to coffee on functional and sensory nutritional properties

An additional question pertains to the effect of milk added to coffee beverages on the nutritional quality of coffee and functional properties

of its phenolic compounds. Simultaneous consumption of milk and coffee may have a negative or masking effect on the nutritional quality and functionality of phenolic compounds in coffee. The negative effect of addition of milk on bio-efficacy of phenols, such as CGAs, in coffee has been noted. However, there is no information on the effects of the addition of milk on the activity or bioavailability of caffeine in coffee beverages (Rashidinejad et al., 2021). Proteins contained in milk can strongly bind/interact with phenolic compounds of coffee (especially, CGAs). Addition of milk to various coffee brews caused a decrease in the concentration of CGA derivatives and their radical scavenging attributes, due to formation of protein-polyphenol interactions (Niseteo et al., 2012). Chlorogenic acids can bind to various milk proteins, such as α -lactoglobulin, β -lactoglobulin, and different types of caseins (Fig. 6).

Protein-polyphenol affinity strongly depends on various factors including type of polyphenol, its solubility, molecular free space, weight, and existence of glycosylate, hydroxylate, and methylate functional groups (Yildirim-Elikoglu and Erdem, 2018). Niseteo et al. (2012) proved that higher molecular weight phenolics and the presence of more methylated functional groups led to a further decrease in polyphenol content and antioxidant properties of coffee brews. Therefore, interaction of coffee phenols with milk proteins may be the main aspect of the negative influence of milk on antioxidant properties of coffee.

4.3. The health-promoting mechanism of coffee

The studies were conducted to assess whether caffeic and chlorogenic acid exert anti-tumor activity in human promyelocytic leukemia (HL-60) cells and human T-cell acute leukemia cells. These compounds (1–100 μ M) did not damage DNA, indicating that they were not genotoxic or mutagenic. However, it was shown that chlorogenic acid at a non-cytotoxic concentration (100 μ M) induced global DNA hypomethylation in T-cell acute leukemia cells. Probably like other phenolic compounds, chlorogenic acid modulates DNA methylation by targeting DNA methyltransferases (Hernandes et al., 2020).

Chlorogenic acid can absorb UVB radiation in the range from 280 to 320 nm. As demonstrated by Cha et al. (2014), UVB irradiation caused damage to DNA of human HaCaT cells. Interestingly, treatment of CGA cells prior to UVB irradiation prevented DNA damage and increased cell survival (Cha et al., 2014).

Consuming dietary antioxidants is important to combat oxidative stress, and to prevent development of various diseases (Tirzitis and Bartosz, 2010). As demonstrated by Balzano et al. (2020) 100% robusta from a Guatemalan sample showed the highest radical scavenging potential with an IC₅₀ value of 1.5 μ g/mL. In addition, robusta showed an IC₅₀ concentration against human lung cancer cells (A549) with a respective value of 61.2 μ g/mL. Interestingly, this value is on the same

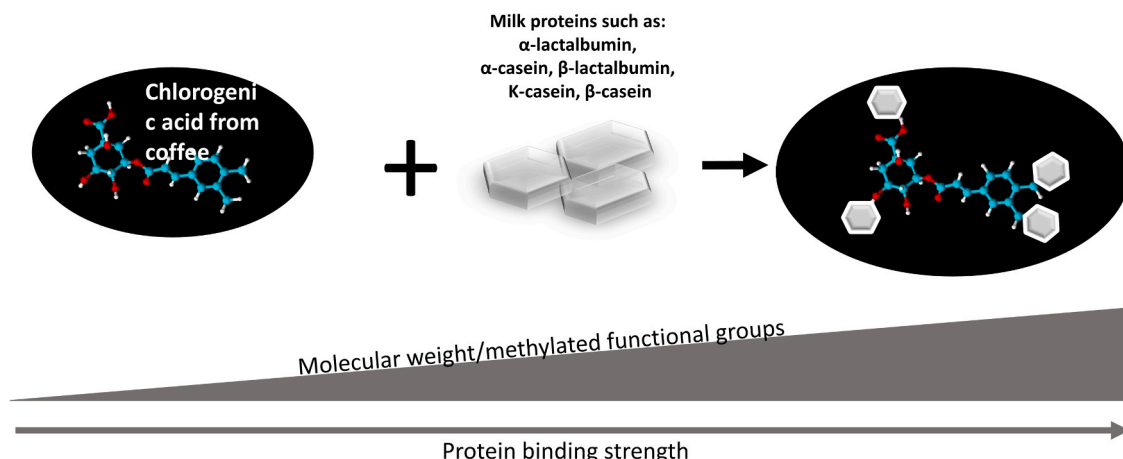


Fig. 6. Possible interactions between chlorogenic acid/polyphenols and milk proteins (Rashidinejad et al., 2021; Niseteo et al. 2012).

level as the control potency of cytostatic vinblastine. Moreover, coffee extract showed a similar antiproliferative activity against human melanoma cells. Earlier, Ramalakshmi et al. (2009) proved that the coffee extracts obtained by arabica and robusta cultivars were able to inhibit proliferation of the P388 cells used as a model of leukemia (Balzano et al., 2020).

Enzyme inhibitors have been used in treatment of various diseases for years and investigated as potential new drugs (Orhan, 2019). By-products, such as Silverskin coffee (CS) and ground coffee (SCG) are produced during the processing of coffee. Silverskin Coffee is a thin coating that covers the coffee beans and is released when roasted. Ground coffee is a residue that is mainly obtained from the production of instant coffee and the brewing process (Janissen and Huynh, 2018). Zengin et al. (2020) investigated the enzymatic activity of Silverskin coffee and spent ground coffee. Inhibitory activity of these coffee against two cholinesterases: acetyl and butyrylcholinesterase were determined. The SCG ethanol extract had the strongest radical scavenging ability and anticholinesterases activity, while water extract of CS samples had the weakest activity of this type. In patients with Alzheimer's disease the level of neurotransmitter acetylcholine is lower and the activity of cholinesterase higher than in healthy individuals; therefore inhibition of cholinesterases by coffee may delay the development of this disease (Mishra et al., 2019). Zengin et al. (2015) also analyzed the activity of α -amylase and α -glucosidase, the important enzymes in diabetes. Inhibition of amylase and glucosidase may delay the increase in blood glucose levels and may control its level in blood (Sun et al., 2019). Those authors have shown that alcoholic extracts of coffee may have higher inhibitory effect on α -amylase and α -glucosidase than the aqueous extracts (Zengin et al., 2020).

5. Summary

Phytochemicals found in coffee and tea are mostly polyphenolic compounds and phenolic acids; those substances are also widely spread in vegetables and fruits. Phenolic compounds exert various health-promoting properties, ranging from free radical scavenging to antiviral and anticancer effects. The presented set of scientific reports on tea and coffee polyphenols can contribute to understanding the health-promoting potential of these beverages. Reports regarding coffee show that its polyphenolic composition, including chlorogenic acid content, decreases during roasting. The degree of coffee roasting becomes an important issue in terms of availability and amounts of polyphenolic compounds and caffeine in various types of coffee. Methods of coffee brewing have also a significant effect on properties of the brew. The presented reports on coffee increase the knowledge in the field of coffee processing. Presented information on different types of coffee and tea, their polyphenolic composition, health-promoting properties and the impact of the preparation method on these beverages properties contribute to increasing consumer awareness when choosing tea or coffee.

6. Conclusion

Due to the presence of polyphenols in tea, it may be possible to help in treat many diseases. By consuming tea polyphenols, the effects of infertility in humans could be reduced. The use of these compounds and the plants themselves in alternative medicine could bring about an improvement in the methods of fighting the Covid-19 virus, which is currently one of the main threats to human life. In addition, increasing knowledge among people consuming either tea or/and coffee about the richness of health-promoting compounds in these plants, may contribute to various diseases prevention by choosing the right type of tea and coffee. In the case of tea, it is worth deciding to consume white and green teas, while in the case of coffee, the situation is similar, the less processed coffee, the greater value of its health-promoting properties.

Thanks to the presented data, it may also be possible to improve the

industrial process of tea and coffee production. Additional information on the industrial processing of tea and coffee, including processing rates and processing temperature of these raw materials, may affect the quality of end products. This knowledge may also increase the amount of health-promoting compounds in an industrial ready-to-sell product, among others, thanks to the appropriate optimization of the production process. Increasing awareness among consumers and producers can be beneficial for both sides.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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