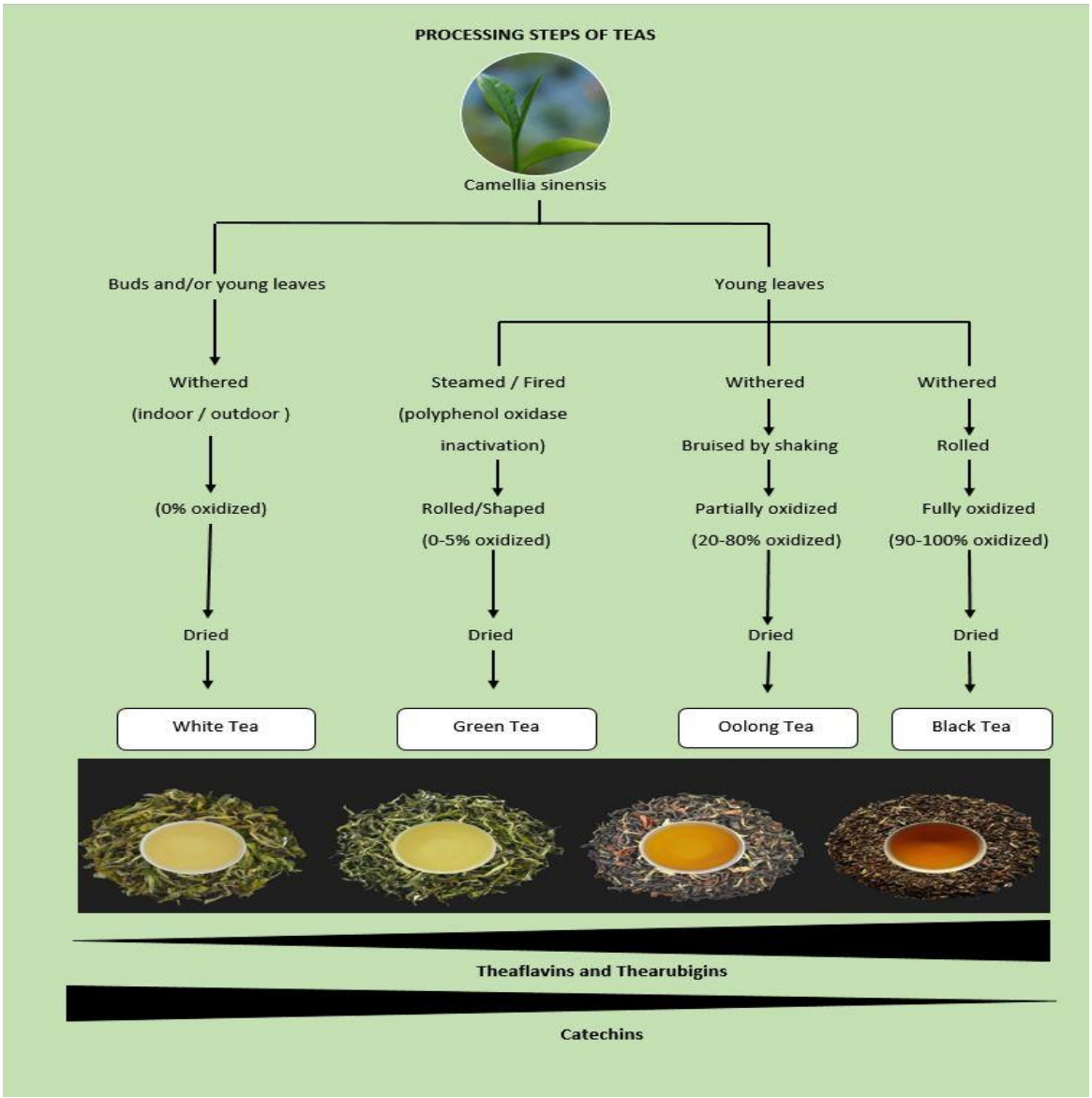
What are polyphenols ?

Polyphenols are micronutrients that naturally occur in plants and found in many plant-based foods like tea, persimmons, cacaos, grapes, red wine, and dark chocolate.

Polyphenolic compounds in food and nutraceuticals represent the most widely distributed plant secondary metabolites exerting their beneficial protective effects as free radical scavengers and chelators of pro-oxidant metals and thus preventing low-density lipoprotein oxidation and DNA strand scission or enhancing immune function. (1)



Tea polyphenols

Polyphenolic compounds constitute one third of dry weight of tea. The major constituents of

tea polyphenolics are divided into four main group as below :

- Flavanols
- Flavonols and flavons

- Precursors of anthocyanidins
- Phenolic acids and depsides

Flavanols and their health benefits

Tea flavanols comprise up to 90% of total polyphenols in fresh unprocessed tea leaves and are known as green tea catechins. The flavanols found in fresh tea leaves are epicatechin gallate (ECG), epigallocatechin (EGC), epigallocatechin gallate (EGCG), epicatechin (EC), catechin (C) and their derivatives.

The most important and distinctive process in green tea processing is the inactivation of oxidation enzymes, especially polyphenol oxidase (PPO), in fresh tea leaves using high temperature via one of steaming (Japan) or pan firing (China) methods. Since the PPO enzyme is inactivated, the catechin content remains intact. Compared to other teas, green tea, the non-oxidized tea, has the highest catechin content (2).

During black tea processing, green tea catechins are oxidized thanks to PPO, a copper-containing enzyme. Oxidation of catechins leads to the formation of theaflavins and therubigins responsible for the formation of the characteristic color and flavor of black tea. The rate and degree of polyphenolic oxidation depends on the composition, distribution, and content of flavanols (green tea catechins) in fresh tea shoots, activity of oxidizing enzymes, degree of tissue damage and cellular disruption, and temperature and oxygen content of the tea leaves during oxidation (1,2).

Oolong tea is oxidized to a limited extent by PPO enzyme and contains a mixture of catechins, theaflavins and thearubigins. The oxidation level in oolong teas ranges from 20% to 80%.

White tea, like green tea is a non-oxidized tea type. It is produced from the buds and unopened first leaves of the hairy varieties of the Camellia sinensis tea plant. Since tea catechins and oxidation enzymes are localized in different organelles in the cells of the tea plant and cannot come together during the gentle processing into white tea, oxidation does not occur. For this reason, white tea is known as non-oxidized tea. However, if it is stored and aged for a long time, slight chemical oxidation can occur. In general, EGCG, the main component of tea catechins, has been reported to be found in higher concentrations in white tea than in green tea (4, 5).

Purple tea is derived from tea varieties whose leaves have purple colouration due to anthocyanin and produced by acceptable processes including oxidation, semi-oxidation and non-oxidation (6). It is one of the newest known tea types, and in addition to its catechin content, it contains a specific polyphenol compound called 1,2-di-O-galloyl-4,6-O-(S)-hexahydroxydiphenoyl-β-D-glucose (GHG). Although GHG itself is a non-catechin polyphenol, its health benefits are similar to catechins (7, 8).

There are many scientific publications on the health benefits of tea catechins and their oxidation products.

Tea catechins have the most effective **antioxidant activity** compared to other tea polyphenols. They are efficient free-radical scavengers due to their one-electron reduction potential. The rate of reaction with free radicals and the stability of the resulting antioxidant radicals contribute to the reactivity of antioxidants (3). Without antioxidants, free radicals that are the metabolic residues of the cells, induce oxidation of carbohydrates, lipids and proteins, and give rise to DNA damage in the body. This situation causes many diseases to occur in the body. Tea catechins, especially EGCG, react quickly with free radicals thanks to their strong antioxidative effects, and prevent them from causing oxidation. Thus, diseases caused by free radicals are prevented.

Numerous in vitro and in vivo trials have been conducted regarding the health benefits of tea catechins and oxidation products of catechins. The results of these studies showed that tea catechins, especially EGCG and oxidation products of catechins, especially the theaflavins, have antiviral, anticarcinogenic, antidiabetic, antimutagenic and antibacterial effects. (9,10,11,12,13,14).

One of the most recent studies is related to the inhibition by EGCG of the SARS-CoV-2 virus, which caused the Covid19 pandemic. In another study, it was stated that EGCG has antiviral effects against many viruses, including widely known viruses such as Hepatitis C, ZIKA virus, Ebola, HIV-1, West Nile Virus, Influenza A and B. Theaflavins, which are black tea polyphenols, have shown antiviral effects against Influenza A and B, Rotavirus, Coronavirus and HIV-1 virus (15).

In both in vitro and in vivo human and animal trials, it has been found that EGCG from green tea catechins and theaflavin from black tea polyphenols have a preventative effect on Parkinson's disease. Many epidemiological studies conducted in this area also support the findings (16).

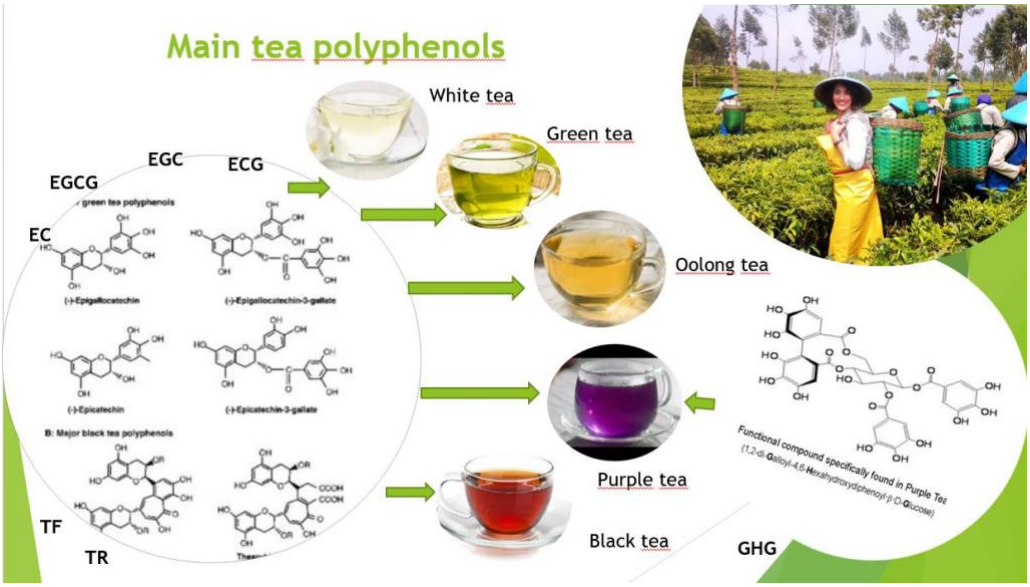
There are dozens of studies on catechins, especially EGCG, that significantly reduce DNA damage thanks to their antioxidant effects and thus reduce the risk of cancer. According to the results of these studies, tea catechins show a protective effect against pancreatic, prostate, lung, breast and esophageal cancer, colon, stomach, bladder and skin cancer (12, 14, 18, 19). The findings of these studies are consistent with the results of epidemiological studies examining the relationship between cancer and tea catechins.

Epidemiological studies show that with increasing tea consumption, cancers especially digestive system cancers decrease due to the intense exposure of digestive system tissues to EGCG and other tea catechins (17).

According to the results of several well-designed epidemiological studies, increased consumption of black and green tea significantly reduced the risk of developing cardiovascular diseases (17).

Green tea catechins, especially EGCG, reduce oxidative stress by scavenging free radicals in the blood serum, thanks to its high antioxidant properties. Thus, it delays aging, that is, it has an anti-aging effect (20).

In summary, we can say that flavanols, which constitute the majority of tea polyphenols, are very important for human health. Among the flavanols, EGCG from green tea catechins and theaflavin, which is the oxidation product of catechins and one of the most important quality markers of black tea, have a special importance.



Flavonols and flavons and their health benefits

As mentioned above, 35% of the dry weight of tea consists of polyphenolic compounds and 90% of these are flavanols. The much smaller group, flavonols, makes up only 0.4% of the polyphenols, while flavones are in still lower amounts.

Tea flavonols are kaempferol, myricetin and quercetin, while tea flavones are apigenin and luteolin and they occur mainly in the form of glycosides, and their content and compositions vary among tea cultivars (21).

In one study, it was observed that flavonols, especially myricetin, were the highest in green tea, followed by oolong tea and black tea, respectively. This suggests that myricetin may be decreased due to enzymatic oxidation. In the same study, it was observed that all three flavonols were significantly reduced in pu'er tea, which is a fermented tea. This can be explained by the fact that flavonol glycosides are significantly degraded by microbial fermentation during the production and storage of pu'er tea. Flavones are a minor class of flavonoids in tea and are the least studied group. It is known that both apigenin and luteolin from flavones have glycoside forms (22).

According to the results of a limited number of scientific studies, flavonols have anticarcinogenic effects by inhibiting the proliferation and angiogenesis of cancer cells. They also have antioxidant effect. It is stated that the antioxidative effects of flavonol glycosides are weaker than those of flavonol aglycones (21).

Further studies are needed to investigate the effects of flavonols and flavons on human health.

Precursors of anthocyanidins and their health benefits

Anthocyanidins also belong in the flavonoid group of polyphenols. Anthocyanins are glycosides of anthocyanidins.

Leucoanthocyanidins and proanthocyanidins found in the tea plant are the precursors of anthocyanidins. The oligomers and polymers resulting from the condensation of catechins and leucoanthocyanidins are commonly referred to as proanthocyanidins (26).

In a study, the average proanthocyanidin content in green tea was found to be 0.84%, while the content in black tea was found to be quite low (0.5%). In the same study, it was observed that proanthocyanidins decreased as the enzymatic oxidation time increased (23).

While proanthocyanidins are found in black, oolong and green teas, polymeric anthocyanidins are found only in purple tea. Most of the anthocyanidins found only in purple tea are in the glycoside form and are known as anthocyanins. Anthocyanins are blue, red, or purple pigments found in plants. It appears as red pigment in acidic conditions while blue pigment anthocyanin exists in alkaline conditions (24).

Non-oxidized, semi-oxidized and fully oxidized purple teas are produced using purple tea clones. It was observed that anthocyanidins decreased due to the increase in oxidation period in purple tea production (7, 8). Fort his reason a green tea process is now preferred fort he purple tea production : to maximise the purple colour.

Purple tea is the only tea rich in anthocyanins. The total anthocyanin content was determined up to 1.53% in purple tea clones (25). It is known that anthocyanins have a very important place in the food and beverage industry due to their strong antioxidant properties. The anthocyanins in purple tea have higher free radical scavenging potential when in the anthocyanidin form. There are studies claiming that purple tea anthocyanins have anticarcinogenic and immunostimulatory effects. Anthocyanins have an important place in the food and beverage industry due to their antibacterial, antidiabetic and antiaging effects (21, 24, 25).

In one study, as well as the normal tea polyphenols, the presence of a special polyphenol compound in purple tea was determined. This polyphenol, called 1,2-di-Galloyl-4,6-Hexahydroxydiphenoyl-β-D-Glucose (GHG), is not found in green tea, oolong tea, and black tea. According to the study, GHG shows excellent anti-obesity and anti-aging effects (8).

Phenolic acids and depsides and their health benefits

Phenolic acids are aromatic secondary plant metabolites. Phenolic acids have been associated with color, sensory qualities, nutritional and antioxidant properties of foods and beverages.

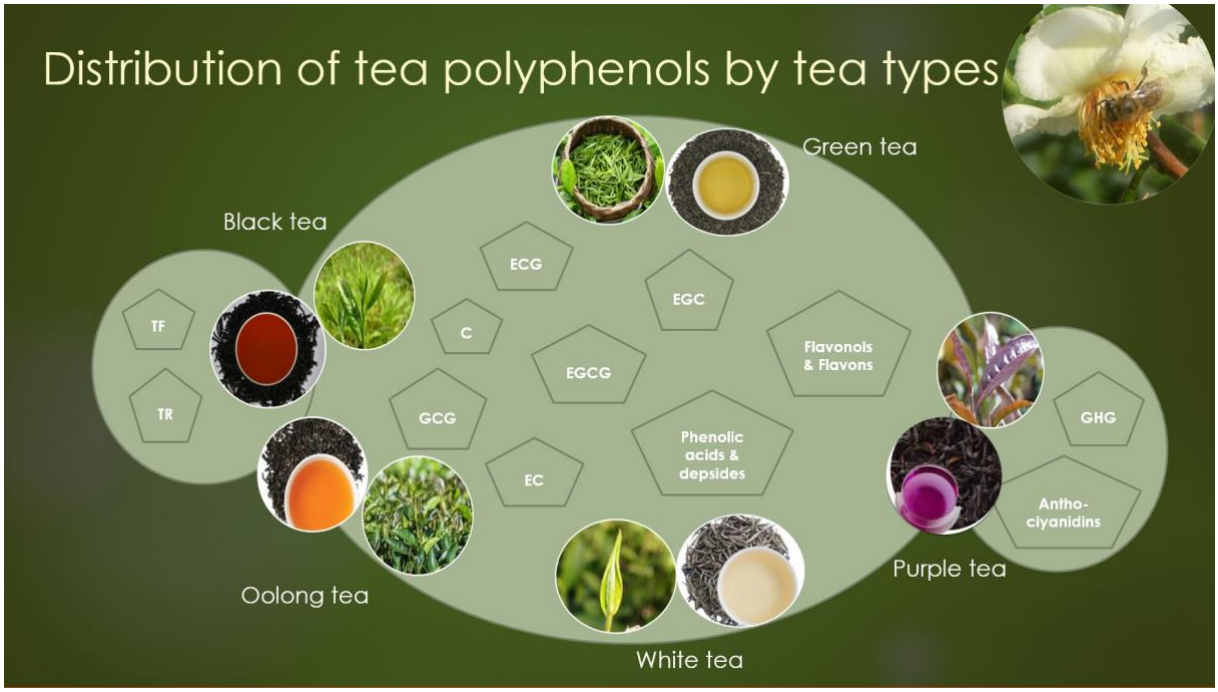
The main phenolic acids in tea are gallic acid and quinic acids, the depsides in tea are derivatives of these two acids. Depsides in tea are theogallin, chlorogenic and p-coumarylquinic acids. Theogallin is a tea-specific depside derived from gallic and quinic acids (27).

There is 50 g/kg of dry weight phenolic acid and depside in fresh tea leaves whereas the amount decreases to 40 g/kg when processed into black tea (1). The reason for this decrease can be explained by the use of gallic acid during enzymatic oxidation.

Free gallic acid is present in tea leaf and enters into interesting oxidation reactions during the manufacture of black tea. Quinic acid is also found in fresh leaf, although it was not recognized until quite recently. While gallic acid is a tea-specific acid, the most abundant phenolic acids in black tea are coumaric, protocatechic, and caffeic acid (27).

These phenolic acids and depsides are strong antioxidants that again possess anti-carcinogenic, antitumor, hepatoprotective, antidiabetic, antimutagenic, anti-inflammatory, immunoprotective, hypocholesterolaemia, antidepressant, antimicrobial effects on human health (28).

To summarize, tea is a beverage particularly rich in polyphenols. These polyphenols can be shown to have a range of anti-carcinogenic, antitumor, antidiabetic, antimutagenic, anti-inflammatory, immunoprotective, hypocholesterolemia, antidepressant, antimicrobial, antiviral effects thanks to their strong antioxidant properties. In addition, considering their antiobesity and anti-aging properties, and their decisive role in the color and sensory quality of tea, polyphenols are very important tea components in both the pharmaceutical and food industry context.



In short, we can say that polyphenols are the nutraceuticals of tea.

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References

1] Shahidi, F., Naczk, M. (2004). Phenolics in Food and Nutraceuticals. CRC Press, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742, page: 247-256.

2] Anesini, C., Ferraro, G. E., & Filip, R. (2008). Total Polyphenol Content and Antioxidant Capacity of Commercially Available Tea (Camellia sinensis) in Argentina. Journal of Agricultural and Food Chemistry, 56(19), 9225–9229. doi:10.1021/jf8022782.

3] Ananingsih, V. K., Sharma, A., & Zhou, W. (2013). Green tea catechins during food processing and storage: A review on stability and detection. Food Research International, 50(2), 469-479. doi:10.1016/j.foodres.2011.03.004.

4] Sharma, P., Joshi, D., Baldi, A., Khatri, K. (2013). White tea: Offering something new to your health. HERBAL TECHNOLOGY/MEDICINAL CHEMISTRY, PharmAspire, 56-66.

5] Dias, T.R., Tomás, g., Teixeira, N.F., Alves, M.G., Oliveira, P.F., Silva, B.M. (2013). White Tea (Camellia Sinensis (L.)): Antioxidant Properties And Beneficial Health Effects : Review Article. International Journal of Food Science, Nutrition and Dietetics (IJFS), ISSN 2326-3350.

6] Anon. (2017). Purple tea — Specification, Kenya National Standard, KS 2745: 2017, ICS67.140.10 (Draft Standart).

7] Khan, F., Bashir, A., Mughairbi, F.A. (2018). Purple Tea Composition and Inhibitory Effect of Anthocyanin-Rich Extract on Cancer Cell Proliferation. Medicinal &Aromatic Plants, 7 :6 ,1000322, ISSN: 2167-0412, DOI: 10.4172/2167-0412.1000322.

8] Anon. (2013). PURPLE TEA EXTRACT Ver. 1.0 SJ, ORYZA OIL & FAT CHEMICAL CO., LTD. No.1, Numata Kitagata-cho, Ichinomiya-city, Aichi-pref., 493-8001 JAPAN.

9] Mhatre, S., Srivastava, T., Naik, S. & Patravale, V. (2021). Antiviral activity of green tea and black tea polyphenols in prophylaxis and treatment of COVID-19: A review. Phytomedicine 85, 153286. https:/ / doi.org/ 10.1016/ j.phymed.2020.153286.

10]] Xu, J., Xu, Z., & Zheng, W. (2017). A Review of the Antiviral Role of Green Tea Catechins. Molecules, 22(8), 1337. doi:10.3390/molecules22081337

11] Ferrazzano, G. F., Amato, I., Ingenito, A., De Natale, A., & Pollio, A. (2009). Anti-cariogenic effects of polyphenols from plant stimulant beverages (cocoa, coffee, tea). Fitoterapia, 80(5), 255–262. doi:10.1016/j.fitote.2009.04.006.

12] Hayat, K., Iqbal, H., Malik, U., Bilal, U., & Mushtaq, S. (2015). Tea and Its Consumption: Benefits and Risks. Critical Reviews. Food Science and Nutrition, 55(7), 939–954. doi:10.1080/10408398.2012.678949.

13] Fu, Q.-Y., Li, Q.-S., Lin, X.-M., Qiao, R.-Y., Yang, R., Li, X.-M., … Liang, Y.-R. (2017). Antidiabetic Effects of Tea. Molecules, 22(5), 849. doi:10.3390/molecules22050849.

14] Yen, G. C. & Chen, H.Y. (1994). Comparison of Antimutagenic Effect of Various Tea Extracts (Green, Oolong, Pouchong, and Black Tea). Journal of Food Protection, Vol. 57, No. I, Pages 54-58 (January 1994).

15] Shaik, F. B., Swarnalatha, K., Mohan, M. C., Thomas, A., Chikati, R., Sandeep, G., & Maddu, N. (2022). Novel Antiviral effects of chloloquine, hydroxychloroquine and green tea catechins against SARS CoV-2 main protease (Mpro) and 3C-like protease for COVID-19 treatment- Review. Journal of Clinical Nutrition Open Science, 42. 62-72. https://doi.org/10.1016/j.nutos.2021.12.004

16] Caruana, M., & Vassallo, N. (2015). Tea Polyphenols in Parkinson's Disease. Natural Compounds as Therapeutic Agents for Amyloidogenic Diseases, 117–137. doi:10.1007/978-3-319-18365-7_6.

17] Higdon, J. V., & Frei, B. (2003). Tea Catechins and Polyphenols: Health Effects, Metabolism, and Antioxidant Functions. Critical Reviews in Food Science and Nutrition, 43(1), 89–143. doi:10.1080/10408690390826464

18] McKay, D. L., Blumberg, J. B. (2002). The Role of Tea in Human Health: An Update. Journal of the American College of Nutrition, 21(1), 1–13. doi:10.1080/07315724.2002.1071918.

19] Santana-Rios, G., Orner, G.A., Amantanaa, A., Provost, C., Wu, S.Y. & Dashwood,R.H. (2001). Potent antimutagenic activity of white tea in comparison with green tea in the Salmonella assay. Mutation Research 495, 61–74.

20]] Maurya, P. K., & Rizvi, S. I. (2009). Protective role of tea catechins on erythrocytes subjected to oxidative stress during human aging. Natural Product Research, 23(12), 1072–1079. doi:10.1080/14786410802267643.

21] Rha, C.-S., Jeong, H. W., Park, S., Lee, S., Jung, Y. S., & Kim, D.-O. (2019). Antioxidative, Anti-Inflammatory, and Anticancer Effects of Purified Flavonol Glycosides and Aglycones in Green Tea. Antioxidants, 8(8), 278. doi:10.3390/antiox8080278.

22] Peterson, J., Dwyer, J., Bhagwat, S., Haytowitz, D., Holden, J., Eldridge, A. L., … Aladesanmi, J. (2005). Major flavonoids in dry tea. Journal of Food Composition and Analysis, 18(6), 487–501. doi:10.1016/j.jfca.2004.05.006.

23] Engelhardt, U. H., Lakenbrink, C., & Pokorny, O. (2003). Proanthocyanidins, Bisflavanols, and Hydrolyzable Tannins in Green and Black Teas. Nutraceutical Beverages, 254–264. doi:10.1021/bk-2004-0871.ch019.

24] Khoo, H. E., Azlan, A., Tang, S. T., & Lim, S. M. (2017). Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food & Nutrition Research, 61(1), 1361779. doi:10.1080/16546628.2017.1361779.

25] Joshi, R., Rana, A., Kumar, V., Kumar, D., Padwad, Y. S., Yadav, S. K., & Gulati, A. (2017). Anthocyanins enriched purple tea exhibits antioxidant, immunostimulatory and anticancer activities. Journal of Food Science and Technology, 54(7), 1953–1963. doi:10.1007/s13197-017-2631-7

26] Joshi, R., Rana, A., Kumar, V., Kumar, D., Padwad, Y. S., Yadav, S. K., & Gulati, A. (2017). Anthocyanins enriched purple tea exhibits antioxidant, immunostimulatory and anticancer activities. Journal of Food Science and Technology, 54(7), 1953–1963. doi:10.1007/s13197-017-2631-7.

27] Graham, H. N. (1992). Green tea composition, consumption, and polyphenol chemistry. Preventive Medicine, 21(3), 334–350. doi:10.1016/0091-7435(92)90041-f.

28] Das, P.R., Eun, J. B. (2016). Phenolic Acids in Tea and Coffee and Their Health Benefits,Phenolic Acids: Properties, Food Sources and Health Effects (pp.129-194) Chapter: 61Publisher: Nova Science Publishers.