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Review : The harvesting process and recent advances on health benefits of white tea

Abstract. The meticulous harvesting process and appropriate post-harvest techniques play pivotal roles in preserving the quality and health benefits of white tea. This careful approach maintains the bioactive compounds such as polyphenols, caffeine, gallic acid, Epigallocationchin (EGC), Epigallocationchin gallate (EGCG), and Epicatechin gallate (ECG), integral to white tea's health benefits. The stability of catechin content in tea plants is greatly influenced by the environment (clone, plant age, leaf age, altitude, temperature, humidity, processing, and pH when storing dry tea). In Indonesia, the raw materials used to produce white tea are mostly pecco from the superior GMB clone Assamica variety which has high polyphenol content (14.83 – 15.43% dry weight). To increase polyphenol levels, the treatment that needs to be considered is the provision of optimum and appropriate fertilizer. The highest catechin content comes from plucking in summer and spring season. Subsequently, controlled post-harvest processes, including controlled withering and drying, safeguard the integrity of active compounds like catechins as antioxidants in white tea, mitigating free radicals and cellular damage. The highest antioxidant showed from 23 hours whithered. The storage time for white tea also has an impact on quality. The content of catechins and amino acids showed a tendency to decrease with storage time. On the other hand, gallic acid increases with the length of storage. The combined effect of these phases, from harvesting through post-harvesting, contributes significantly to white tea's health benefits, encompassing cardioprotective effects, anti-diabetic potential, prevention of anticarcinogenic and antimutagenic activity, neuroprotective properties, and antimicrobial attributes.

Keywords: Antioxidant · Bioprospecting · *Camellia sinensis* · Health · White Tea

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Introduction

Tea is one of the beverages with sensory properties, stimulant effects, and a health impact. Those benefits make tea the second largest beverage after mineral water (Dias et al., 2013). A large amount of tea consumption can be reflected in its production and consumption value, which reaches three billion kilograms annually, where most of the production supply is produced from Southeast Asia (Hayat et al., 2015). Not only the taste and aroma, the antioxidant content of tea which has many benefits for the body is a consideration for people when consuming it (Hajiboland, 2017). Tea has potential as a source of antioxidants and contains more than 700 chemical compounds, such as flavonoids, amino acids, theanine, vitamins (B, C, E, and K), caffeine, polysaccharides, and catechins. The most widely studied positive role of tea for human health includes normalizing blood pressure, lowering blood cholesterol levels, fighting cardiovascular disease, cancer, diabetes mellitus, obesity, central nervous system and microorganism-based diseases (Sanlier et al., 2018; Shao et al., 2019; Sharma et al., 2013).

The raw material for shoots greatly influences the quality of the tea produced. Quality tea comes from 2-3 young leaves and a bud. This part of the plant is rich in polyphenolic compounds, caffeine, and amino acids that affect the quality of the taste, aroma, and color of the tea produced. Today's popular tea types are green, oolong, black, and white (Ajisaka & Sandiantoro, 2012).

There are two groups of well-known tea varieties: the first one is the Assamica variety from Assam (India) with large leaves, and the second one is the sinensis variety originating from China with small leaves (Wachira et al., 2013). Most tea plants cultivated in Indonesia are hybrids of natural crosses between Assam tea and Sinensis tea with an Assam-type tendency. Considering that the most significant tea production in Indonesia is black tea and planters require high plant productivity, the tea clones recommended by the Indonesia Research Institute for Tea and Cinchona (RITC) are Assam-type clones (Sriyadi, 2011).

The simplest processing method is applied to white tea, consisting solely of extended drying and withering operations without any fermentation or enzyme deactivation stages. (Dai et al., 2017, Tan et al., 2016). White tea is processed naturally through withering and drying with the help of wind and sunlight immediately after the plucking process is carried out, without undergoing any oxidation fermentation processes or grinding so as not to damage the actual shape of the tea (Tohawa, 2013). The raw material for making white tea consists of 2 types, namely shoots (*Camellia sinensis*) that are still curled, called pecco, and shoots with one or two young leaves, called peony. White tea comes from tea shoots that are still buds, small in size, and have white hairs commonly called silver needle (Hajiaghaalipour et al., 2015). Dried tea leaves can contain around 30-42% polyphenolic compounds in the form of catechins (Bag et al., 2022; Rabbani et al., 2019). The stability of catechin content in tea plants is greatly influenced by the environment, such as clone, plant age, leaf age, altitude, temperature, humidity, processing, and pH when storing dry tea (Zeng et al., 2018). White tea has a variety of content that is beneficial to health, including polyphenols, caffeine, theogallin, gallic acid, theaflavins, flavonol glycosides, epigallocatechin (EGC), epigallocatechinalatine (EGCG), and epicatechinalatine (ECG) (Islam, 2011). The strong antioxidant activity of white tea is largely due to its high content of EGCG, ECG, and EGC as these catechins represent approximately 80-90% of the total catechins in tea leaves (Lee et al., 2014).

The chemical compounds in tea leaves consist of three major groups with many health benefits: polyphenols, caffeine, and essential oils. The substances contained in tea are very easily oxidized. The oxidation process occurs when tea leaves are exposed to sunlight (Ajisaka & Sandiantoro, 2012).

This review describes white tea's production process, chemical content, and health benefits. Thus, it is expected to provide information about white tea and its potential as antioxidant bioprospecting.

Subject Matter

White Tea Benefits for Health. Tea contains several bioactive compounds which are believed to have various physiological properties, including stimulant and antidepressant, anti-inflammatory, antioxidant, antiatherosclerotic, antihypertensive, anti-infective, antimutagenic, anticarcinogenic and anticancer promoting antimicrobial, hypolipidemic, hypocholesterolemic, neuroprotective, and antidiabetic agents. Tea also enhances the immune. This physiological mechanism is attributed to the chemical properties of polyphenols and their healthful antioxidant effects, even though it's still controversial. Despite the abundance of data on the phenolic constituents, antioxidant activity, and ameliorative effects of green and black teas on health, the information on white tea is still less discoverable, which is the rarest and least processed tea (Dias et al., 2013).

Tea leaves contain 30-40% polyphenols, most of which are known as catechins. Pecco shoots produce highest catechin content varying between 8.36%-18.22% between other parts of the leaf. The catechin content in other parts of the leaves are first leaf between 5.78%-13.48%, second leaf between 4.43%-15.81%, and internodes + stalk leaves between 1.78%-12.15% (Martono & Setiyono, 2014). The catechin content in white tea makes white tea a functional drink that has benefits for the body compared to other types of tea.

Catechin is a component that determines the quality of tea leaves which is colorless, soluble in water, and can influence the taste, color and aroma of tea (Anjarsari, 2016). Catechin is a bioactive compound with a flavan-3-ol framework which is a strong antioxidant, stronger than glutathione, vitamin E, vitamin C, and β-carotene (Grzesik et al., 2018, Sutarna et al., 2013). Tea-derived catechins exhibit remarkable antioxidant activity due to their ability to neutralize free radicals and increase the activity of detoxifying enzymes, including glutathione peroxidase, catalase and glutathione reductase (Kochman et al., 2020). In the body, catechins help the performance of the superoxide dismutase (SOD) enzyme which functions to get rid of free radicals (Martono, 2015). The main catechin group compounds consist of 8 types, including: catechin (C), epicatechin (EC), gallocatechin (GC), epigalocatechin (EGC), catechin gallate (CG), epicatechin gallate (ECG), gallocatechin gallate (GCG), and epigalocatechin gallate (EGCG) (Sang et al., 2011). Among this group of catechins, EGCG is present in the largest number and has been carried out in many health studies (Xing et al., 2019). One of the characters that indicates catechin content can be seen in the astringent and bitter taste of drinks with significant correlation values (Xu et al. 2018). Meanwhile, morphological characters also indicate the compound content in tea. Morphological characters that are significantly correlated with catechin content are stomata density and leaf angle (Khomaeni, 2015).

White tea contains more catechins and their derivatives than any other tea. The epigallocatechin gallate (EGCG) component of white tea positively affects health. White tea protects against cardiovascular disease, cancer, diabetes mellitus, obesity, central nervous system, and microorganism-based diseases (Sanlier et al., 2018).

a. Cardioprotective Effect. Natural antioxidants, such as polyphenolic compounds from food, can inhibit lipid oxidation and weaken the rate of atherosclerosis and thrombosis. An epidemiological study showed that populations in Europe with higher concentrations of natural antioxidants, L-ascorbic acid, and -tocopherol in plasma had lower cases of coronary heart disease. Several epidemiological studies have shown that flavonoid intake is inversely related to coronary heart disease mortality. Tea catechins effectively reduce cholesterol absorption from the intestine, lower cholesterol solubility, and increase fecal excretion of cholesterol and total lipids. Other components of tea, especially quercetin and L-theanine, reduce blood pressure in animals and humans and lower the risk of disease development (Kobayashi & Ikeda, 2017; Yoo et al., 2020; Chen et al., 2020).

b. Antidiabetic. There is some evidence that tea is a hypoglycemic agent. In-vitro studies of mice show that EGCC of other catechins and theaflavins helps prevent hyperglycemia by increasing insulin activity and possibly by preventing cell damage. All studies show that polyphenols do not increase insulin secretion but reduce insulin resistance and improve insulin sensitivity (Liu et al., 2021, Manhas & Khan, 2022).

c. Anticarcinogenic and Antimutagenic.The polyphenols in tea play an essential role in cancer prevention by reducing DNA damage in cells and reducing cancer activation leading to malignancy (Majidinia et al., 2019). Many studies have shown that tea and its constituents, particularly EGCG, are antimutagenic and anti-inflammatory by intercepting carcinogenic agents and reducing oxidant species before damaging DNA (Shariare et al., 2020).

d. Neuroprotection Activities. Isolated tea constituents have previously been shown to exert a protective effect on nerve cells. For example, EGCG has been shown to have neuroprotective activity in experiments using mice, and an epidemiological study showed that the risk of Parkinson's disease was reduced when tea consumption was 2 cups/day (Pervin et al., 2018; Luo et al., 2021).

e. Antimicrobial Properties. Tea also exhibits antimicrobial properties, mainly due to its polyphenols. The level of this activity depends on the bacterial species and the polyphenol structure. Due to differences in the outer membrane, gram-negative bacteria are more resistant to polyphenols than gram-positive bacteria. The antimicrobial activity of non-fermented teas is higher than that of semi-fermented or fermented teas. In addition, the most increased antimicrobial activity occurred in samples with the highest total polyphenol concentration and antioxidant activity. Thus, white tea is expected to have higher antimicrobial activity than other teas. The main components responsible for antimicrobial activity are EGCG and EGC, which also have more antioxidant activity. EGCG at 10–100 M has been shown to reduce the growth of Escherichia coli by about 50% (Dias et al., 2013).

World Tea Production. Based on annual bulletin data (International tea committee, 2022) Indonesia is the 6th tea producing country in the world, namely 127.00 M.Kg. The largest tea producing country is still occupied by China 3063.15 M.Kg, then second by India 1343.06 M.Kg and respectively Kenya 537.83 M.Kg, Sri Lanka 299.34 M.Kg and Vietnam 180.00 M.Kg. In Indonesia, the largest production is black tea, followed by green tea production. White tea production in Indonesia is still small, there is no clear data that shows the amount because white tea production is limited in each tea plantation so white tea consumers are still quite limited.

White Tea Production. White tea comes from the tea plant (Camellia sinensis), like green and black tea. White tea is made from very young and un-bloomed Camellia sinensis leaf buds, commonly called pecco. The pecco was still covered with fine silver-white hairs, giving the impression of a velvety white color, with a needle-like shape commonly called silver needle. Apart from that, white tea can also be made from shoots with one or two young leaves, called peony. The ideal time and weather for plucking white tea is early morning when the sun is high enough to dry out any remaining moisture on the buds. Plucking is not done on rainy days or during the snow season (Zhao et al., 2019). The highest catechin content comes from plucking in summer and spring season (Paiva et al., 2021; Ma et al., 2022).

White tea is often plucked in the morning when the humidity is still high (Maulana et al., 2019). To avoid the tea leaves breaking, this process is carried out very carefully. To retain the flavor and aroma of white tea, the leaves should be selected which not fully opened yet (Braber et al., 2011). In addition, plucking white tea at the right time, especially at certain growth phases, can affect the number of bioactive substances contained in tea (Kaur et al., 2019). Tea farmers play a very important role in this situation.

Based on the data of tea plantation division of Research Institute for Tea and Cinchona (IRITC), white tea production in Indonesia is usually made from pecco which produces silver needle. A case study conducted at IRITC as the biggest white tea producer in Indonesia, shows that the raw material for white tea production is taken from Pecco, which is then sorted into several variants when the raw material arrives at the factory. Not all of the pecco raw materials plucked from the garden will become silver needle. For pecco that is still a complete needle and has not been opened, it will be a silver needle grade. Meanwhile, for pecco that has opened it is called white leafy and the sorting results for pecco that are plucked and then open into shoots that have one to two young leaves are classified as white peony. Another type of white tea is when silver needles are combined and pressed into a round pearl shape, it is called white pearl tea. Based on data taken from white tea production at IRITC during September 2018-August 2023, pecco production as a raw material for white tea ranges from 7-10 kg per hectare depending on the season. White tea processing has an average processing yield of 25% so it will produce 1.75 - 2.5 kg of dry tea/ha. Pecco plucking is done manually and the pluckers is required to be skilled and have expertise in plucking.

In China, the withering process of white tea varies depending on region. Sometimes, the plant must be shaded a month or more before the shoots are plucked to produce white tea, so it has lower levels of chlorophyll and higher polyphenol antioxidants but is very low in caffeine. The lack of processing in white tea makes white tea a premium health tea with the highest polyphenol antioxidant content of all tea types (Tohawa, 2013). In Indonesia, the raw materials used to produce white tea are mostly pecco from the superior GMB clone Assamica variety which has high polyphenol content, namely (14.83 - 15.43% dry weight). Polyphenols in tea are responsible for the formation of tea color, taste strength, and partly for flavor in the beverages and further benefits health. In an effort to increase polyphenol levels, the treatment that needs to be considered is the provision of optimum and appropriate fertilizer (Maulana et al., 2020; Rezamela et al., 2020).

Tohawa (2013) said that in producing quality white tea, the processing is a stage that needs to be considered. Not only does it produce a delicious taste, aroma and brew, but good processing can also maintain the antioxidant compounds in the raw materials of white tea so that it can produce white tea that brings optimum benefits to the body. White tea processing does not go through a fermentation step, the same as oolong or black tea. The process is without deactivating enzymes like green tea. White tea only goes through decolorization and drying. To prevent oxidation, the tea` leaves were immediately evaporated and dried after collection (Sanlier et al., 2018).

White tea processing usually only goes through two stages: withering and drying. Sometimes, the same processing methods as sun drying can be considered as withering and drying. The earliest processing method was sun drying (Maulana et al, 2020). Sun withering increasing the concentration of flavone glycosides and astringent flavonoids in white tea (Zou et al., 2022). Modern white tea can be produced through sun drying, airing, and basket frying. Although the modified withering is better than natural withering (Chen et al., 2012). White tea can be produced in spring, summer, and fall but not in winter. Usually, spring white tea is of premium quality, followed by autumn white tea. The ideal time and season for plucking is in the morning when it is summer, and the sun is high enough to dry out and reduce moisture in the tea shoots (Dias et al., 2019; Jenny & Mao, 2013).

The Silver needle white tea processing process includes the plucked tea shoots being immediately brought to the white tea processing plant and placed on an aluminum tray for the withering process (Maulana et al., 2020). Withering tea shoots in the sun from 11 a.m. to 3 p.m. and continues overnight indoors. The processing step was repeated for four days. In the last step, it is dried in an oven at 60°C until the moisture content obtained by the product is 3-4%. The tea samples were packed in aluminum foil and stored in a room with a relative humidity (RH) of 60%.

White peony tea is processed in two simple steps: withering and drying (Jiang, 2009). Withering is the key that determines the final quality of white tea. There are usually three withering methods for white peonies: sun withering, drying, and low-temperature withering. Drying is the most widely used method for White Peony. The spring drying requirements are 18-25°C, and the relative humidity (RH) is 67-80%. Typically, temperatures of 30–32°C and RH of 60–75% are more acceptable for drying in summer and autumn. Drying time is usually 52-60 hours (Jenny & Mao, 2013).

The white peony tea processing processes include plucking 1-2 leaves and a bud, sorting, withering at a temperature of 27°C for 20 hours on a winnowing tray and arranging on a withering rack, aerated with a fan to make air circulation smoother and temperature regulation with Air Conditioner (Ulandari et al., 2019). Furthermore, it withers back with indirect sunlight for approximately one hour until a distinctive aroma appears on the tea leaves. The tea leaves are steamed at 90°C for 2 minutes, then re-aired until cold. Rolling with the Top Roller (TR) machine for 5 minutes until the tea leaves roll perfectly. They were dried in an oven at 90°C. This drying process causes white peony tea to have a moisture content of 4-5%. The drying process was carried out for 60 minutes at a temperature of 90°C.

Long-time withering is the key process for the manufacturing of white tea and the dynamic changes of the characteristic metabolites. The white tea that produced from withering a bud in 96 hours observation indicated the oxidation reaction still running after plucked. Despite the minimum processing step of white tea manufacturing, total polyphenols of the leaves are decreasing, whereas a small amount of theaflavin detected and reducing but thearubigin detected in the experiment are increasing (Maulana et al., 2020).

During withering, the content of tryptophan, histidine, isoleucine, lysine, phenylalanine, proline, leucine, valine, and tyrosine significantly increased. The level of glutamic acid and aspartic acid also decreased significantly, especially during the first 20 hours of withering. The highest antioxidant showed from 23 hours whithered (Paiva et al., 2021). After 36 hours of withering, almost half of their content was lost. During the withering process, the levels of the metabolites, which included theaflavins, theaflavins 3-gallate, theaflavins digallate, theasinensin A, and theasinensin B, significantly increased. The dimeric catechin metabolites included flavonol-O-glycosides and flavone-C-glycosides, and their fold changes reached up to 15. The levels of the methylated catechins of EGC 3-methylgallate and EC 3-O-(3-O-methylgallate) catechins. The predominant metabolites in the group were flavonol-O-glycosides and flavone-C-glycosides, and they remained quite stable. Over the course of the first 28 hours, the levels of methylated catechins of EGC 3-methylgallate and EC 3-O-(3-O-methylgallate) increased, and between 28 and 36 hours, they slightly declined. Procyanidins, benzyl primeveroside, linalool primeveroside, and linalool oxide primeveroside, as well as metabolites such as catechins of GC, GCG, C, EGC, and EC, all saw a considerable drop during the withering process. Compared to the original composition in fresh leaves, less than 50% of the GC, GCG, and C content was retained in the finished white tea product. After the 36-hour withering process, the tea leaves contained between 59 and 90% of the fragrance primeverosides (Dai et al., 2017).

The storage time for white tea also has an impact on quality. The content of catechins and amino acids showed a tendency to decrease with storage time. On the other hand, gallic acid increases with the length of storage (Ning et al., 2016).

Conclusion

White tea is a functional drink that has benefits for the body compared to other types of tea. The meticulous harvesting and precise post-harvesting practices profoundly influence the quality and health-enhancing properties of white tea. The careful selection of leaves pecco and one or two young leaves, called peony, harvested during optimal atmospheric conditions and specific growth phases, ensures the retention of vital bioactive compounds like polyphenols and catechins, Epigallocationchin (EGC), Epigallocationchin gallate (EGCG), and Epicatechin gallate (ECG). The stability of catechin content in tea plants is greatly influenced by the environment, such as clone, plant age, leaf age, altitude, temperature, humidity, processing, and pH when storing dry tea. In Indonesia, the raw materials used to produce white tea are mostly pecco from the superior GMB clone Assamica variety which has high polyphenol content, namely (14.83 – 15.43% dry weight). To increase polyphenol levels, the treatment that needs to be considered is the provision of optimum and appropriate fertilizer. The highest catechin content comes from plucking in summer and spring season. Moreover, the controlled post-harvest processes, such as withering and drying, preserve these compounds, notably catechins, known for their antioxidant properties among 8.36% -18.22%, shielding the body from free radical damage. The highest antioxidant showed from 23 hours whithered. The storage time for white tea also has an impact on quality. The content of catechins and amino acids showed a tendency to decrease with storage time. On the other hand, gallic acid increases with the length of storage. The cumulative effect of these practices underscores white tea's multifaceted health benefits, including its potential in cardioprotection, diabetes prevention, anti-carcinogenic and antimicrobial activities, neuroprotection, and more.

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