IJPSR (2024), Volume 15, Issue 3 (Review Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 28 April 2023; received in revised form, 22 February 2024; accepted, 25 February 2024; published 01 March 2024

PURPLE TEA: A SYSTEMATIC REVIEW

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Keywords:

Purple Tea, Anthocyanins, Catechins, Flavonoids, Antioxidants

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ABSTRACT: *Camellia sinensis* has been used since several decades owing to its numerous health benefits. The purpose of this study is to investigate the developments in new varieties of *Camellia sinensis*. This new variety of tea possesses striking, purple-colored leaves, and hence, it is more commonly referred to as purple tea. This study analyzes the detailed mechanism of color change. An over-expression of genes in *C. sinensis* leads to an increase in the proportion of its anthocyanin content which is responsible for its color change. The genes accountable are CsAN1 (R2R3-MYB transcription factor), CsGL3 and CsEGL3 (bHLH transcription factor) and CsTTG1 (WD repeat protein). This feature stimulated us to review purple tea. The review article discusses its history, taxonomy, geography, process of cultivation and collection with the appropriate harvesting seasons, macroscopic and microscopic characteristics, and its extraction processes. The constituents obtained from *Camellia sinensis* and the chemical structures of its phytoconstituents were also discussed. The therapeutic properties like anti-diabetic, anti-allergic, anti-pyretic, anti-inflammatory, anti-oxidant anti-aging and anti-parasitic associated with C. sinensis are also described. *C. sinensis* can also be used for the treatment of osteoarthritis, obesity and cardiovascular diseases (atherosclerosis, hypertension). Furthermore, it provides protection to gastro-intestinal tract from excess secretion of gastric acid and bones from abnormal hormonal levels. It also possesses other properties for treatment of chronic diseases like Cancer and Alzheimer's.

INTRODUCTION: Tea, scientifically known as *Camellia sinensis*, is a popular beverage consumed worldwide for its numerous health benefits. Recently, there has been considerate development regarding a new variety of tea, known as Purple Tea, which gets its name due to its unique purple color. This color is believed to be prominent due to the accumulation of anthocyanin - a purple color pigment belonging to the family of flavonoid compounds.

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.15(3).614-25

This article can be accessed online on www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.15(3).614-25

This tea is mainly cultivated and developed in countries like India, China, Japan and Kenya [1]. It is primarily grown at high elevations in areas with a cool climate. Just like the traditional black tea, it has a mild earthy, sweet taste [2].

Along with the presence of eight anthocyanin fractions, purple tea also contains gallic acid, caffeine, free amino acids and polyphenols such as epigallocatechin (EGC), catechin, epicatechin (EC), epigallocatechin gallate (EGCG), and epicatechin gallate (ECG) – all of which are of great importance in improving health [3]. Studies have shown that regular consumption of the polyphenols, such as in purple tea, is beneficial in assisting anti-diabetic, anti-aging, anti-inflammatory, anti-pyretic, anti-allergic and anti-

parasitic activity. Additionally, catechins present in the tea are also effective in treating other serious illnesses like Osteo-Arthritis, Cancer, Alzheimer's, and certain cardiovascular diseases [4, 5]. This paper presents an overview of various aspects of purple tea such as its cultivation, extraction, phytoconstituents, microscopy, mechanisms of color change and its various health benefits.

History: Originally discovered in the gardens of Assam, India, Purple tea captured its interest by standing apart from the traditional green colored leaves because of its rich purple color [6].

Twenty-five years later, after the bush was given to The Tea Research Foundation of Kenya, its genetic clone TRFK 31/8 was breathed into existence. TFRK 31/8 is now used as the standard yield control clone to determine the performance of the new variety, TRFK 306/1, produced for commercial use. This cultivar was developed by cross-breeding of traditional tea with its anthocyanin-rich cousin *Camellia irrawadiensis*. First introduced as seedlings to small-scale Kenyan farmers in 2011, it has quickly gained renown after its five-year investment plan.[7] Since then, four additional producers have entered the market. Estimates suggest that purple tea will account for approximately $60 million i.e., 5 percent of Kenya's tea exports [8].

Taxonomical Classification:

Kingdom: Plantae

Subkingdom: Viridiplantae

Division: Tracheophyta

Class: Magnoliopsida

Family: Theaceae

Genus: Camellia L

Species: *Camellia sinensis*

Biological Source: It contains prepared purple leaves and leaf buds of *Camellia sinensis* (Linne) kuntz., belonging to family Theaceae.

Geographical Source: It is mainly grown in India (Assam), Sri Lanka, China, Japan and Kenya.

Cultivation and Collection: *Camellia sinensis* is an evergreen shrub cultivated across the world but primarily in countries like India (Assam), China, South and Southeast Asia, Sri Lanka, East Africa, Japan and Mauritius [9, 10]. The plant requires well drained, sandy, moist, thoroughly aired, loamy, deep and nutritious with a healthy layer of hummus [11]. It prefers acidic soil i.e., low, or neutral pH soil ranging between 5 to 7. Tea is well-cultivated in cool temperatures of 14-27^{o} C; Purple Tea is grown in cooler conditions [13,] it prefers a wet summer and a cool but not very frosty dry winter with an annual rainfall in the range 70-310 cm [9]. However, the crop yields best quality plants between rainfall of 250-300 cm and temperatures of 18-20 °C [11]. The plant requires at least 5 hours of direct or 11 hours indirect sunlight daily, but can grow favorably in semi-shade [9, 11]. It is cultivated at extremely high elevations of between 4500-7500 feet resulting in strong antioxidant properties [13] and is sometimes grown at altitudes as high as 3000 m from sea level [11].

Tea plants are propagated sexually by seeds and asexually by vegetative propagation [11]. Stored seeds are soaked for 24 hours in warm water and the hard covering around the micropyle should then be filed down to leave a thin covering. It takes about one to three months for germination to occur, and once seedlings are large enough to handle, they are potted into individual pots and grown in light shade in a greenhouse for their first winter. Once they cross the 15cm mark, they are replanted into their permanent position for 1-3 years outdoors. A seedling takes about 4-12 years before they start to produce seeds [9]. Bushes take 3 to 6 years to mature [13]. The harvest time may differ based on environmental conditions [12]. The harvesting depends upon the availability of young terminal buds and adjacent leaves of tea plants. Once the tea plants are fully grown, they are trimmed to produce shoots in a regular manner [10].

The level of elevation is an essential factor in determining the amount of catechin in tea. Higher altitudes cause an increase in amino acid content increases and decrease in the quantity of polyphenols. Although higher altitudes cause a decrease in the yield of tea, there is a considerate increase in the quality of crops produced.

Vice-versa, increased irrigation causes growth in height and the number of new leaves, however there is an ultimate fall in quality due to lower level of catechins [12]. Additionally, extreme conditions like drought, excessive heat, water logging and frost are also responsible for decreases in the yield and quality of tea plant. Excess rainfall, in areas such as Sri Lanka, also limits the growth and sunlight absorbed [11]. There are several types of tea, such as white, oolong, black and purple tea, prepared from *Camellia sinensis* (L.) O. Kuntze (Theaceae), which vary considerably depending on their differences in fermentation processing, leading to variations in taste and aroma [11]. For harvesting purple tea, the leaves are hand-plucked for purple leaves only (two leaves and a bud) and allowed to slightly wither. They are lightly pan-fried to arrest further oxidation, and dried, after which they are packed for shipment for commercial use.

TABLE 1: HARVEST SEASONS [11]

	Spring	Monsoon	Autumn/Winter	Summer
China	Best quality (March to mid-May)	Lower quality (May to September)	Quality better than monsoon but lower than spring	-
India	-	Low quality, often not harvested (Mid-June to August)	Best quality (September to October)	-
Japan	Better quality (Mid-April to May/June)	-	-	Poor quality, often not harvested Mid-June/Early July to end August/September)
Sri-Lanka	Best quality (January to March)	Lowest quality (May to August)	Best Quality (December to January	-

Macroscopy and Microscopy: The purple tea plant mostly possesses characteristics that resemble green tea plant – an evergreen shrub that can reach heights up to 9 meters, possessing dark green elliptical, serrated-edged, pointy leaves. They are hairy in nature. White-yellow flowers may grow solitarily or in clusters of 2-4. However, the predominant differentiating factor that stands the two varieties apart is the flush of purple color due to the presence of anthocyanins [14].

Transverse section of the leaf shows the upper epidermis with presence of polygonal cells with slight wavy walls and a thick cuticle and the lower epidermis with smaller cells containing stomata. The mesophyll is asymmetric in nature with two layers of parenchyma cells, characterized with a number of sclerenchymatous idioblasts varying in shape. Calcium oxalate crystals are also present in the spongy parenchyma. Vascular bundle, consisting of xylem and phloem, is covered by a band of pericyclic fibers [14].

Morphological observation through Standard Electron Microscopy determined the change in characteristics during the three developmental stages of tea leaf i.e., Juvenile Green (JG), Light Purple (LP), and Dark Purple (DP). Differences were observed in terms of morphological characters like cell size, shape, and structure. While cell size and stomatal number decreased as leaves developed from JG to DP, dark purple leaves were more likely to acquire flocculent structure. Analysis of pigments (chlorophyll, xanthophyll, anthocyanin) recorded a decrease in chlorophyll and xanthophyll content, and an increase in anthocyanin content which is a remarkable property of purple tea, as leaves progressed to DP stage. Moreover, DP tea leaves were also found to possess an increased rate of photosynthesis as compared to LP and JG due to increased activity of chlorophyl ATP synthase subunit [3].

A study comparing the level of photosynthetic pigments, proanthocyanidins, anthocyanin and lignin was carried out, which found that the concentration of photosynthetic pigments was low in purple tea leaves compared to green tea leaves. The level of proanthocyanidin was 7.05% higher compared to green leaves. The anthocyanin concentration was 6.2-fold higher in purple tea leaves whereas the lignin concentration was lower in purple tea leaves.[15]

Mechanism of Color Change: The uniqueness of this tea is mainly due to its distinctive purple color,

which occurs as a result of hyper-accumulation of anthocyanin in the plant. Anthocyanins are biosynthesized from the flavonoid biosynthetic pathway in the cytosol of the cell, and then the glycosylated end products are deposited in the vacuole [16]. Plant anthocyanins show different transition in colors like red, purple, or reddish violet, in the form of cyanine glycosides after methylation, acetylation and glycosylation from an anthocyanin monomer. The concentration of anthocyanin in purple leaves was found to be 707 μg·g −1 Dry Weight in Zijuan tea (*Camellia sinensis*), which is 10-fold higher than the concentration usually found in normal tea varieties [17]. In case of purple tea leaves, a gradual color change is seen. Firstly the juvenile leaves are green in color, which later show transition to light purple color, and finally dark purple color as they pass through various stages of growth and development [3]. With the use of various biotechnologies, researchers have stated that anthocyanin is due to upregulation of genes such as CsAN1 (R2R3–MYB transcription factor), CsGL3 and CsEGL3 (bHLH transcription factor), and CsTTG1 (WD-repeat protein). Studies have also shown that the direct or indirect interaction of proteins, photosynthesis processes, transcription factors and anthocyanin biosynthesis involved in metabolism leads to the color change of purple tea leaves [18].

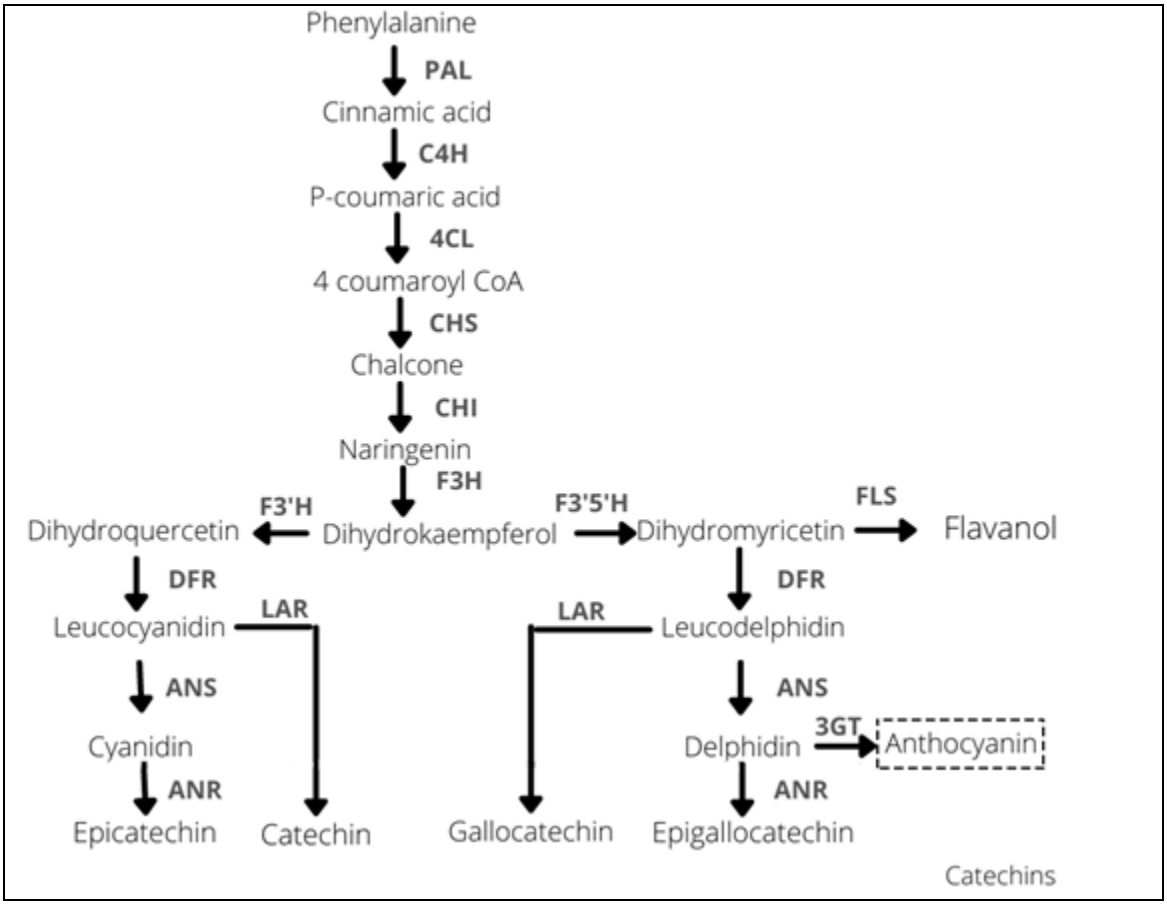

FIG. 1: MECHANISM OF COLOR CHANGE

The various structural enzymes involved in synthesis of anthocyanin in purple tea leaves include: phenylalanine ammonialyase (PAL), cinnamic acid-4-hydroxylase (C4L), 4-coumarate: CoA ligase (4CL), chalconesynthase (CHS), chalconeisomerase (CHI), flavanone 3-hydroxylase (F3H), flavonoids 30 -hydroxylase (F30H), dihydrofavonol4-reductase (DFR), and anthocyanin synthase (ANS). Studies have found that the activity of PAL was 2-fold higher in purple leaves than in green ones. In addition, it was found that CHI activity in the purple leaves was significantly greater compared to that in green ones, which explains the increase in anthocyanin level in purple tea leaves [17, 19]. In anthocyanin synthesis, gene expression levels are regulated by transcription factors such as R2R3-MYB, bHLH, WD40, and HY5.[17] Studies have revealed that activation of the

R2R3-MYB transcription factor (TF), anthocyanin1 (CsAN1) specifically upregulated the bHLH TF CsGL3 and anthocyanin late biosynthetic genes (LBGs) to accumulate in purple tea. It was also found that CsAN1 interacts with bHLH TFs (CsGL3 and CsEGL3) and WD-repeat protein CsTTG1 to form the MYB-bHLH-WDR (MBW) complex [16]. In leaves of purple tea, this MYB–bHLH–WDR complex regulates anthocyanin accumulation by activating mRNA expression of F3H, DFR and ANS. The abundance levels of bHLH 66-like and bHLH 135 in purple leaves were significantly higher than those in green leaves tea, and the mRNA expression level of bHLH was also higher in purple leaves.[17] Another protein, long hypocotyl5 (HY5) also found in abundance as compared to green tea was observed andreported that HY5 also regulates anthocyanin biosynthesis by inducing the transcriptional activation of the MYB75/PAP1. Thus, higher abundance of bHLH and HY5 may increase the transcription of anthocyanin biosynthetic genes [17].

Phytoconstituents:

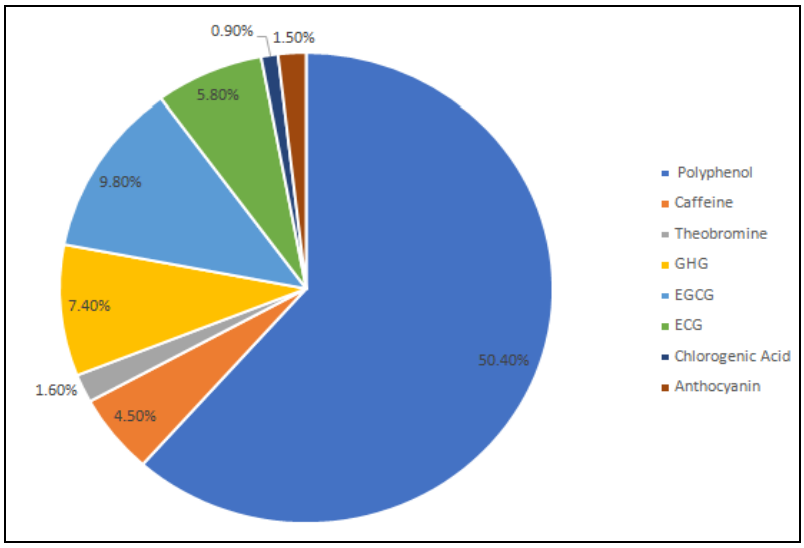

FIG. 2: PIE CHART SHOWING COMPARISON OF PHYTOCONSTITUENTS

Purple tea consists of various phytoconstituents such as alkaloids, flavonoids, polyphenols, tannins, saponins, steroids, terpenoids and anthocyanins [18]. Among them, anthocyanin is the most important and is also responsible for the purple color which distinguishes this tea from other types of teas. Anthocyanin is a water-soluble pigment and belongs to the family of compounds known as flavonoids [20]. Anthocyanins are classified as glycosides of polyhydroxy or poly-methoxy derivatives of 2-phenylbenzopyrylium and consist of two benzoyl rings in between a heterocyclic ring, which in turn form the flavylium cation. Anthocyanins are most commonly present as tri-, di- or mono-saccharide units and when hydrolyzed, anthocyanins yield anthocyanidins and sugars [21]. Purple tea shows presence of 8 anthocyanin fractions which are pelargonidin-3,5-diglucoside, cyanidin-3-O-galactoside, cyanidin-3-O-glucoside, delphinidin, cyanidin, pelargonidin, peonidin, and malvidin, among which malvidin is the most predominantly detected anthocyanin for some plants cyanidin-3-O-galactoside for other plants. This difference is observed mainly due to difference in the genotype and the environment of plant growth [22]. Polyphenols found in purple tea consist of catechins such as epigallocatechin (EGC), catechin, epicatechin (EC), epigallo-catechin gallate (EGCG) and epicatechin gallate (ECG). These catechins are responsible for the antioxidant property of tea [22]. Catechin synthesis is done using malonic acid-and shikimic acid metabolic pathways [23]. Since high amount of gallic acid is also present in the tea, it is derived as an intermediary product during shikimic acid pathway [20, 23]. The amount of catechin found in purple tea is less when compared with other varieties of tea [20]. Regarding free amino acids, tyrosine and cysteine, lysine, alanine, aspartic acid, methionine, valine and isoleucine are found in trace amounts. Alkaloids such as caffeine and theobromine are also found. Caffeine is mainly a trimethyl

derivative of purine 2, 6-diol [23]. The amount of caffeine found in purple tea is lower than other varieties of tea such as green and black tea. This difference may be attributed to the genotypic factors [18, 20].

Purple Tea extract contains total polyphenol (50.4%), caffeine (4.5%), theobromine (1.6%), GHG (7.4%), EGCG (9.8%), ECG (5.8%), chlorogenic acids (0.9%), total anthocyanin (1.5%) [18].

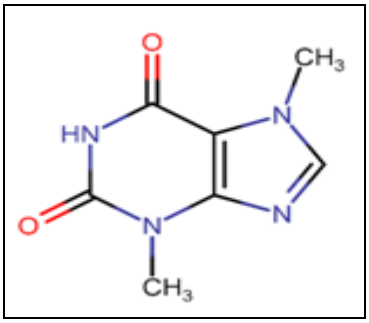

FIG. 3A: THEOBROMINE

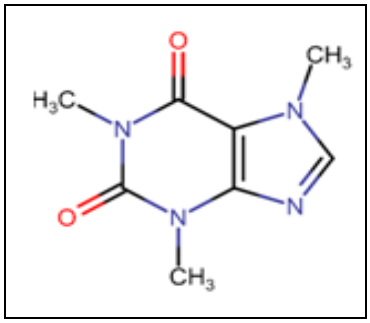

FIG. 3B: CAFFEINE

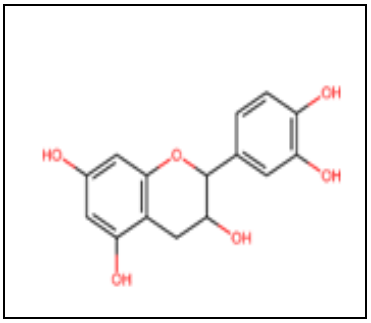

FIG. 3C: (+) CATECHIN; (-) EPICATECHIN

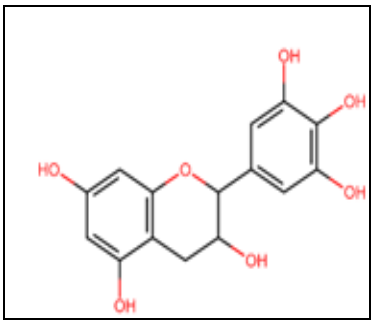

FIG. 3D: EPIGALLOCATECHIN

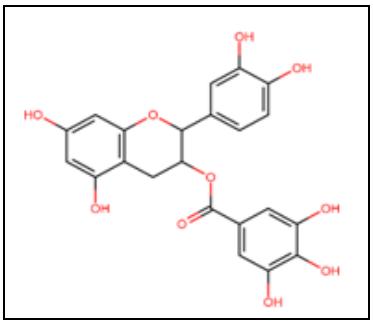

FIG. 3E: EPICATECHIN GALLATE

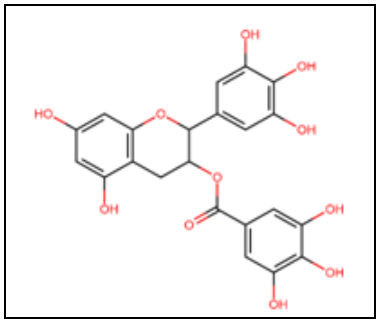

FIG. 3F: EPIGALLOCATECHIN GALLATE

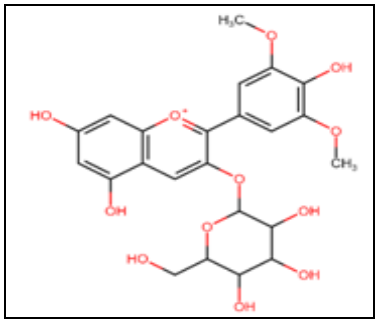

FIG. 3G: CYANIDIN-3-O-GALACTOSIDE

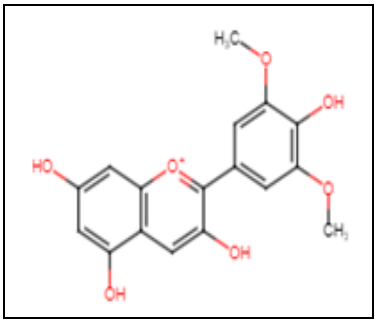

FIG. 3H: MALVIDIN

Extraction of Phytoconstituents: Several isolation techniques such as Soxhlet extraction, heated reflux extraction (HRE), organic solvent extraction (OSE), and maceration are commonly used for extraction of bioactive compounds [24]. Some recent developments in modernization of extraction techniques have proved to be more advantageous as compared to conventional degrees due to higher

degrees of sophistication and improved performance. These methods generated higher yields of extractions at much lower temperatures and utilized low extraction time, thus producing high quality extracts. Some of these are: Ultrasound-Assisted Extraction (UAE), Microwave-Assisted Extraction (MAE), Microwave Assisted High Pressure Extraction, Ultrasound/Microwave Assisted Extraction (UMAE), Supercritical Fluid Extraction (SFE), Subcritical Water Extraction (SCWE), High Hydrostatic Pressure Extraction (HHPE), Pulsed Electric Field (PEF) processing, Accelerated Solvent Extraction (ASE), Sequential Alkaline Extraction method (SAE) and others [24, 25].

Ultrasonic Assisted Extraction showed better efficiency in the extraction of tea polyphenols, amino acids and caffeine as compared to conventional extraction strategies. UAE effectively increased the extraction efficiency of catechin and decreased the extraction time and solvent consumption [24].

A new molecularly imprinted polymer (MIP) prepared using catechin as a template enabled selected extraction of catechin from tea samples with high selectivity.

Efficient extraction of phytoconstituents largely depends on the type of solvents used. A range of highly polar solvents like water, ethanol, and methanol, and non-polar solvents such as n-hexane, are often used for successful extraction of a wide variety of compounds with varying polarity. Other factors that affect the extract yield are extraction temperature, extraction time, pH of the extract as well as the nature of compound to be extracted [25].

The combination of solvents generally used for extraction of phytochemicals from tea are as follows [24]:

- Flavonoids - ethanol, methanol, water, and combinations of these solvents
- Catechins – ethanol, ethyl acetate, n-butanol, n-hexane, deep eutectic solvents

In case of extraction of bioactive molecules of tea, it has been proved that higher temperatures and increased extraction time leads to degradation of such compounds. For example, UAE extraction of polyphenols gives better yield at 65^{o}C as compared to 85^{o}C. Often, combinations of higher temperature and decreased extraction time, or a lower temperature and increased extraction time are modified to provide optimum results [25, 26].

Therapeutic Properties

Osteoarthritis [27, 28, 29, 39]: The phytoconstituents present in *C. sinensis* are useful for patients with Osteoarthritis. Polyphenols, principally catechins, have anti-arthritic property. The catechins present in major concentration are epicatechin, epicatechin-3-gallate, epigallocatechin and epigallocatechin-3-gallate (EGCG). A study on mouse as an experimental model suggests that EGCG has ability to regulate PGE2, chemokines, and cytokines expression.

The suppression of prostaglandin E2 (PGE2) is done by inhibiting Cyclooxygenase-2 (COX-2) enzyme (similar to NSAIDS). These chemicals have a prominent role in inducing and maintaining inflammation in joints. In patients with Osteoarthritis, the level of these inflammatory mediators is significantly high. Additionally, the study suggests that EGCG can be used for prophylactic purposes. Moreover, the expression of Interlukin-6 (IL-6) is also down regulated by EGCG. IL-6 is another molecule which induces Arthritis in cartilages of synovial joints and is also involved in Gout.

Obesity [31, 32]: Obesity is a common problem observed in several countries across the world, which has potential to cause other metabolic disorders which could sometimes prove fatal. Research conducted by Hiroshi et.al studied the efficacy of purple tea phytoconstituents in controlling obesity. Results have suggested that extracts of *C. sinensis* can reduce the gain in bodyweight. BMI and body fat mass also show marked reduction in body fat ratio. As fat content decreases, muscle mass ratio increases. By inhibition of lipid absorption in intestines, serum triglycerides have also been shown to reduce. This was observed by olive oil ingestion which contains esters of oleic, linoleic and palmitic acid. In another study conducted on animal model, lower amount of fat was deposited in the adipocytes of mice. Thereby, hyperlipidemia can be prevented.

Other metabolic disorders such as fatty liver disease can also be prevented by consumption of purple tea. As *C. sinensis* extracts increase hepatic elimination of cholesterol, there is evident lowering of blood cholesterol levels. Furthermore, enzymes like alpha-ketoglutarate, pyruvate dehydrogenase – both of which are required for biosynthesis of Cholesterol – and squalene epoxidase, the rate limiting enzyme in cholesterol biosynthesis are also inhibited.

Anti-Cancer [33, 34, 35, 36]: Catechins, one of the most prominent phytoconstituent of *C. sinensis*, possesses anti-cancer effects. Many researchers have reported that catechins have the potential to inhibit matrix metalloproteinases. Matrix metalloproteinases are enzymes that degrade components of extracellular matrix (ECM) and aid in tumor invasion. A study by Ahmad *et. al* also reported that EGCG found in purple tea disrupts the cell cycle progression in tumor cells. EGCG induces cyclin kinase inhibitors which, by downregulation of cyclin, impedes the cycle progression at G0-G1 phase. Another strategy by which cancer cells metastasize is angiogenesis. *C. sinensis* extracts can suppress angiogenesis in cancer patients by inhibiting Vascular Endothelial Growth Factor (VEGF). Some cancers are induced as a result of harmful effects of ultra-violet light. These types of cancers can also be suppressed by oral administration of purple tea.

Anti-Alzheimer's/Dementia [37, 38]: Alzheimer's is a disease characterized by deposition of beta amyloid plaques and neurofibrillary tangles in brain. This leads to degeneration of neurons, which are responsible for memory retention, thereby inducing dementia. In research done on animal models by Kavon *et. al*, it was reported that EGCG extracted from purple tea has anti-amyloidogenic effect. A 50mg/kg dose of EGCG markedly reduced deposition of beta amyloid plaques in hippocampus region, cingulate cortex region and entorhinal cortex region of brain. This study also suggested that memory performance was improved by EGCG treatment. Moreover, as EGCG also possesses anti-ageing property by down regulation of the pro-apoptotic genes responsible for cell apoptosis, it can also be employed in the geriatric population as they are more prone to Alzheimer's and Dementia. EGCG also exhibits antioxidant activity and has greater potency than Ascorbic Acid (Vitamin C) and Tocopherols (Vitamin E).

Cardiovascular Diseases [39, 40]: Several studies have suggested that drinking purple tea is beneficial in the treatment of cardiovascular diseases. Hartley *et. al* reported that drinks, capsules and tablets made of extracts of *C. sinensis* can be used as prophylaxis in cardiovascular diseases. Trials conducted on human subjects have reported that subjects consuming *C. sinensis* extracts showed significantly lower levels of low-density lipoproteins (LDL), biomolecules that are deposited in the arteries of the heart. This deposition of lipids thickens the blood vessels and interferes with physiological blood flow. Since the heart does not receive sufficient oxygen, hypoxia occurs. This condition is termed Atherosclerosis and the deposits are called as Atherosclerotic plaque. Hartley et. al also confirmed that the systolic and diastolic pressure were also lowered in test subjects. In another study by Antonello *et. al*, systolic and diastolic pressure induced by doses of Angiotensin II was reduced by *C. sinensis* extracts especially EGCG. These observations indicate the efficacy of *C. sinensis* extracts in treating hypertension.

Anti-diabetic [41, 42, 43]: Purple tea has been known to possess a number of phytochemicals such as alkaloids, flavonoids, phenols, tannins, saponins, steroids and terpenoids. However, only polyphenols like catechins, flavanols, theaflavins and thearubigins, have the potential to decrease the risk of diabetes mellitus.

The presence of epigallocatechin gallate (EGCG), the most abundant and powerful antioxidant present in tea, has been proven to assist in Type 1 Diabetes Mellitus. It acts by inhibiting the inflammatory factors and reducing the reactive oxygen species, thereby reducing the production of nitric oxide synthase (iNOS). This protects the function of pancreatic Islet β-cells. Clinically, it has demonstrated promise by lowering blood glucose 4th and 6th hour after administration. Another water-soluble compound, gallic acid, reduces blood glucose level by promoting the transport of glucose into skeletal muscles. Additionally, lowering of blood glucose levels also occurs due to presence of catechins which inhibit the carbohydrate digestive

enzymes. Thus, glucose production decreases in the GT, which results in overall lower levels of glucose, which in turn reduces serum glucose level, and finally decreases liver glycogen.

Lastly, Purple tea has also been reported to increase insulin sensitivity. This occurs due to an increase in RBP-4 signaling from mature adipocytes, which increase insulin-stimulated glucose uptake in adipocytes, thereby decreasing cellular glucose uptake. This mechanism has also been determined to occur due to presence of EGCG.

Anti-ageing/Antioxidant [44, 45, 46, 47, 48]: Biological aging is particularly characterized by certain oxidative stress parameters, namely erythrocyte malondialdehyde (MDA), glutathione peroxidase (GPx) or glutathione reductase and catalase (CAT). Accumulation of lipid peroxidation (LPO) and reactive oxygen species (ROS) takes place, thereby deteriorating cellular enzymes. This leads to progressive loss of structural organization, diminishing functional capacity and other neurological disorders.

Catechins, normally found in purple tea, have been known to prevent oxidative damage in the brain by activation of antioxidative enzymes. Intake of catechins causes an age-dependent increase in erythrocyte MDA level and a decrease in GSH and membrane–SH group concentration, thereby providing protection to erythrocytes against oxidative stress.

Decreased membrane GSH, and thus, increased brain glutathione levels account for an increase in brain anti-oxidant capacity. This increase in brain GSH imply the neuroprotective potential of purple tea in neurodegenerative conditions.

The presence of fine dust particles in the air has led to severe signs of skin aging in most population. The most prominent tea-catechin, epigallocatechin gallate (EGCG), stimulated skin aging in human dermal fibroblasts (HDFs) by scavenging ROS. Collagen synthesis was recovered, and intracellular elastase and collagenase activities were inhibited, thereby making EGCG a potential molecule for FDP-induced skin aging. In SAMP10 mice with accelerated senescence, catechin intake was proven to suppress cerebral atrophy. Additionally, in the Caenorhabditis elegans organism model, catechins improved the tolerance of worms to oxidative stress by germline signaling pathways, thus proving its anti-oxidant and anti-aging potential.

Anti-Inflammatory [49, 50]: Anthocyanins have been considered as key modulators of inflammations, however, other phytochemicals like alkaloids, flavonoids, steroids, and tannins may also exert some anti-inflammatory effects.

It is also suggested that Purple Leaf Tea may ameliorate inflammation by increasing the population of beneficial gut species such as Ruminococcaceae. These bacterial species possess the ability to degrade cellulose and hemicellulose, which are then converted into short chain fatty acids (SCFAs) by the process of fermentation. These SCFAs have been shown to protect against inflammation

In a study involving reproducible mouse models with Post-Treatment Reactive Encephalopathy (PTRE), mice that did not receive any antioxidant treatment with Kenyan Purple Tea anthocyanins of coenzyme-Q10 showed a more marked presence of inflammatory cells.

Anti-Pyretic: Little is known about the anti-pyretic activity of purple tea, only that it helps reduce fever in some cases, however there is no particular scientific evidence to support the same.

Anti-Allergic [51, 52]: Purple tea has been known to possess some significant immunomodulatory properties, owing to the presence of saponins, polysaccharides, and polyphenols like catechins. Although the exact inhibitory mechanism remains undefined, some hypotheses have been put into place, of which EGCG plays an important role. EGCG causes inhibition of NADPH oxidase translocation in mast cells, which are believed to play a central role in the initiation of allergic immune response. The phytochemicals act by inhibiting allergen–IgE complex formation and reducing FcεRI expression or allergen–IgE complex binding to FcεRI, thus helping to alleviate symptoms of allergy.

Additionally, the presence of tealeaf saponins (TLF) was proven to strongly inhibit histamine release, a chemical mediator involved in allergic reaction.

IR and UV–Visible spectroscopy analysis of purple tea extract revealed the presence of bio-active compounds, which could exert its clinical effects in conditions such as asthma, allergic rhinitis, other food and respiratory allergies, atopic dermatitis, and anaphylaxis.

ACE Inhibition / Blood Pressure Regulation [53, 54]: GC-MS based isolations of tea infusions and decoctions identified a total of fifty-one metabolites, which included the presence of organic and inorganic acids, amino acids, sugars, alcohols, phenols, flavonoids, and fatty acids.

These metabolites, including catechins, were found to significantly reduce the activity of membrane-bound Angiotensin-converting enzyme, an important chemical mediator found in blood pressure regulation. The exact mechanism of this inhibition was determined to be the conversion of hippuryl-l–histidyl-l-leucine to hippuric acid.

Gastrointestinal Protection [55, 56]: The gastro-protective effects of purple tea may be attributed to the following mechanisms: increasing the content, thickness, pH, and blood flow to the gastric mucus, and reducing the gastric acid output.

In albino rats with ethanol-induced gastric ulcers, Camilla sinensis offered protection by inhibiting the 5- lipoxygenase pathway.

Anti-parasitic [57, 58]: Purple tea demonstrated some anti-parasitic effects owing to the presence of catechins. Catechin gallate inhibited the recombinant *T. cruzi* arginine kinase, a key enzyme in the energy metabolism of the parasite by about 50%. Camilla sinensis Purple Tea also demonstrated the potential to inhibit the Acanthamoeba parasite by exerting lethal effects on Acanthamoeba cysts.

Prevention of Bone Degradation [59, 60]: Certain findings in bilaterally ovariectomized rat model have suggested that aqueous tea extracts may be effective in preventing bone loss due to ovarian hormone deficiency. However, the exact underlying mechanism for the same remains unknown. Other observed actions are increase in serum estrogen level, prevention of bone loss, increase in bone density), and preservation of microarchitecture of bone.

CONCLUSION: Nature has bestowed mankind with innumerable resources which can truly be utilized for various ailments. Purple tea is one such example which has a high anthocyanin profile. In this review article, we have discussed the pharmacognostic aspects of *C. sinensis*, some mechanistic insights on color change and its numerous therapeutic properties which is exhibited majorly by a class of phytochemicals i.e., polyphenols. Polyphenols especially Epigallocatechin gallate (EGCG) have great potential to treat fatal diseases like cancer which synthetic anti-cancer drugs and Radiotherapy didn't cure satisfactorily. Also, it could treat those neurodegenerative diseases which are, till date, still declared as 'Only Manageable'. However, there are some questions that pose unanswered like its efficacy in human studies, side effects and other adverse effects associated with use of polyphenols as drug. If thorough research is conducted in future, it will surely prove to be a boon for humans.

ACKNOWLEDGEMENT: The authors would like to express their gratitude to the researchers and scholars in the field whose work laid the foundation for this review. They also would like to thank the editorial team and reviewers for their constructive feedback and suggestions during the review process. Their input has significantly enhanced the clarity and coherence of this article

CONFLICTS OF INTEREST: Ms. Vishaka G. Thakur, Ms. Niki Jain, Ms. Nikita Khule, Ms. Nimisha Raut, and Mr. Talha Siddiqui have no competing interests to declare.

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How to cite this article:
Thakur VG, Jain N, Khule N, Raut N and Siddiqui T: Purple tea: a systematic review. Int J Pharm Sci & Res 2024; 15(3): 614-25. doi: 10.13040/IJPSR.0975-8232.15(3).614-25.