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BIOACTIVE COMPOUNDS OF TEA (CAMELLIA SINENSIS) FLOWERS

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ABSTRACT

Tea is an economically important non-alcoholic beverage-yielding plant for North East India and some parts of South India. Flower morphology is important to plant breeding as they provide important information on flower nature. Different bioactive compounds are present in Tea flowers which have multiple beneficial effects in tea drinkers. Genetically flowers are also different and major genes responsible for total catechin content in tea flowers such as chalcone synthase (CH2) and flavonol synthase (FLS) were found to be highly expressed during early flowering stage, while genes such as phenylalanine ammonia lyase (PAL1) and flavonoid 3'-hydroxylase (F3'H1) were expressed in the late flowering stage. Pserphids are main pollinators of tea. Though identification of morphological and genetically nature breeding becomes easy and higher success rate. The presence of health-beneficial bioactive molecules in tea flowers has been globally acknowledged.

KEYWORDS: Beverage, Bioactivity, Genetics, Tea Flowers

INTRODUCTION

The beverage "tea", made from the bud and first two leaves of the plant *Camellia sinensis*, has cemented its place as the world's second most loved and consumed non-alcoholic beverage, just after the "elixir of life", i. e., water. For years China had claimed to be the country of origin of this aromatic beverage. However, existence of its Indian counterpart (*Camellia assamica*) had also been eventually established (Mondal*et al*, 2019; Rawal*et al*, 2020). Tea is preferred mainly due to its strong aroma and stimulating effects. It is saturated with bioactive components which not only energize a drinker, but also contribute to innumerable health benefits (Chen *et al* 2012; Matsuda *et al* 2012; Wang *et al*, 2012; Wang *et al* 2017).

Bioactive Compounds

Tea flowers contain various bioactive chemicals which include

Catechins and Caffeine

The major health-promoting polyphenols in tea are catechins, theaflavins and thearubigins. As theaflavins and thearubigins areformed during black tea processing, as such are unavailable in flowers. Even though catechin content in tea flowers is lower as compared to tea leaves, however,it is significant enough to consider them as a second source. The major catechins found in tea flowers are +catechins (+C), epicatechin (EC), gallocatechin (GC), epigallocatechin (EGC), catechins gallate (CG), epicatechingallate (ECG), gallocatechingallate (GCG) and epigallocatechin gallate (EGCG) (Lin *et al*, 2003; Yang *et* *al*, 2007, Yang *et al*, 2009; Morikawa*et al*, 2013b). Among all, EGC, ECG and EGCG have found to be the most prominent catechins in tea flowers. Caffeine, on the other hand, is present only at 0.3-1.1 % of total tea flower dry weight (Lin *et al*, 2003; Morikawa*et al*, 2013b) in comparison to 2-3 % of total tea leaf dry weight (Nagata and Sakai, 1984; Ashihara, 2006).

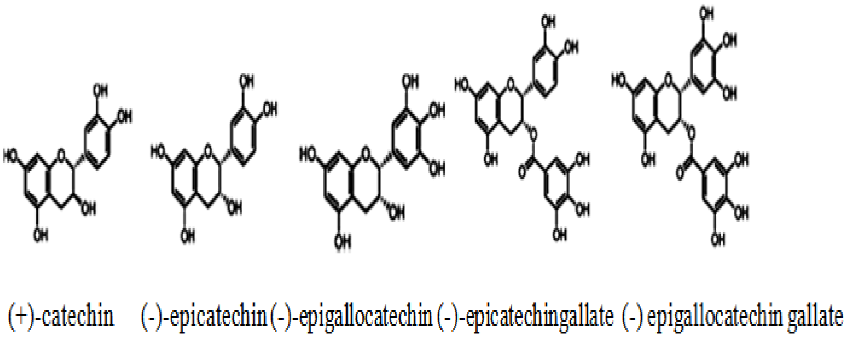

Figure 1: Structure of Major Catechins Found in Tea Flowers.

Volatile Compounds

Aromatic compounds in tea leaves are synthesized via the terpenoid or shikimic acid pathway, or are results of fatty acid and carotenoid degradation (Yang *et al*, 2013). In spite of a similar constitution of aromatic compounds in both tea leaves and flowers, the volatiles acetophenone and 1-phenylethanol are highly expressed in tea flowers (Dong *et al*, 2012, 2016; Zhou *et al* 2014, 2015). The composition of volatile aromatic compounds in tea flowers differ depending on the cultivar, geographical location and extraction procedure (Joshi *et al*, 2011a; 2011b; Wang *et al*, 2015). Supercritical Fluid Extraction (SFE) has been found to be superior to distillation extraction methods (SDE) as the heat-labile volatiles are retained during SFE resulting in better floral fragrance and aroma. Terpenoids, both free and glycosidically bound, form a major part of the aroma components in tea flowers. The major terpenoids found in tea flowers include linalool, linalool oxides, geraniol, nerolidol and α-terpineol, found at various stages of flowering. Additionally, other components such as benzaldehyde, glutaraldehyde, hexanoic acid, 2, 4-di-tert-butylphenol, methyl palmitate, methyl linoleate, methyl salicylate and β-ionone also add to the volatile components in tea flowers (Joshi *et al*, 2011a).

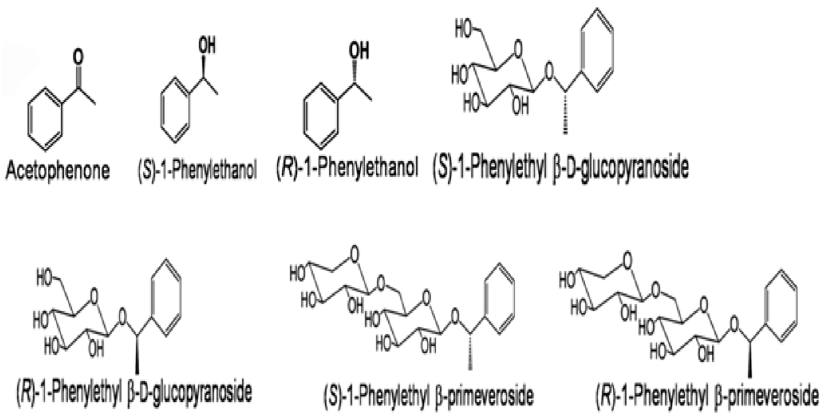

Figure 2: Major Volatiles in Tea Flower.

L-Theanine

L-theanine is a non-proteinogenic amino acid found most commonly in tea (genus Theaceae). It is the most common free amino acid found in tea and accounts to 1-2 % of totaltea leaf dry weight (Wan, 2003; Wan and Xia, 2015), up to 6 % of total tea root dry weight (Li *et al*, 2019)and around 0.8 % of total tea flower dry weight (Wang *et al*, 2010a).

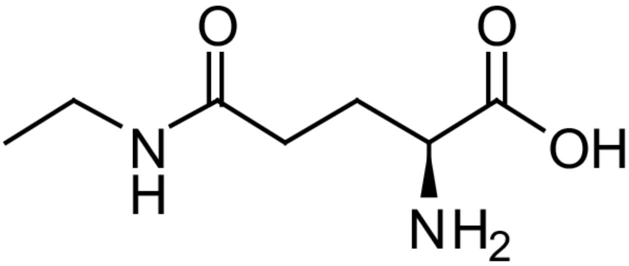

Figure 3: Structure of L-Theanine Found In Tea Flowers.

Polysaccharides

Polysaccharides have two major roles in plants- as structural components and/or as reserved components. Consequently, the composition of polysaccharides in different parts/organs of plants differs. The polysaccharide content in tea flowers (5.24 %) have been found to be higher as compared to tea leaves (3.64 %) (Wang *et al*, 2010b).As for the composition,tea flower polysaccharide (TFPS) composition differ depending on the method of extraction used. Contrary to microwave or ultrasonic-assisted extraction, traditional water extraction was found to be optimal for the extraction of TFPS (Wei *et al*, 2010). Furthermore, water extract was found to contain glucose: xylose: rhamnose: galactose in the ratio 1.0:1.2:0.81:0.98, whereas ethanol extract comprised of glucose: xylose: rhamnose: arabinose in the ratio 1.0:0.76:2.3:2.3 (Han *et al*, 2011b).

Saponins

Saponin concentration in different parts of a plant varies, with its highest concentration found in seeds (Wan and Xia, 2015). Tea flowers have been found to contain higher saponin content (0.47-4.23 % dry weight) (Morikawa*et al*, 2012) than tea leaves (0.04-0.07 % dry weight) (Zhen, 2002).Till date, 26 saponins have been identified in tea flowers which include Floratheasaponin A-K, Chakasaponin I-VI, Floraassamsaponin I-VIII and Assamsaponin E (Sugimoto *et al* 2009; Matsuda *et al*, 2016; Ohta*et al*, 2015, 2017). Composition of saponins, however, differ depending on the geographical region. The saponin composition in tea flowers of India were found to be similar to those in Anhui Province in China but were different from the tea flowers in Japan (Yoshikawa *et al*, 2008).

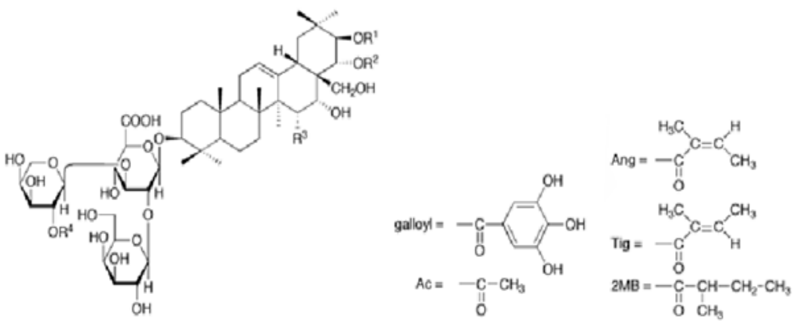

Figure 4: Basic Backbone Structure of Saponin In Tea Flower.

Proteins

The total protein content in tea flowers is 30-50 % of dry weight as compared to 20-30 % of dry weight in tea leaves (Weng, 2004). One of the most important commercially used proteins is the protease enzymes which convert complex proteins to amino acids for quicker absorption. A protease enzyme extracted from tea flowers have been found to increase the amino acid content of tea infusion up to 177 %, a competence far greater than any commercially available protease (Chen *et al*, 2016).

Sperm Dine Derivatives

The composition of spermidine derivatives in tea leaves and flowers are considerably distinct. A principal component analysis of the different metabolites in tea leaves and flowers using ultra-performance liquid chromatography/time-of-flight mass spectrometry revealed differences in metabolite profiles between the two types of samples. Four spermidine derivatives namely N^1, N^5, N^{10}-tri-coumaroyl spermidine, coumaroyl di-feruloyl spermidine, feruloyl di-coumaroyl spermidine,and tri-feruloyl spermidine were detected and isolatedfrom tea flowers which were absent in tea leaves. Furthermore, a reduction in the content of spermidine conjugates was observed during flower development and was found to concentrate primarily in the anthers (Yang *et al*, 2012). The role of spermidine derivatives in plants range from floral induction and flower formation to sexual differentiation, tuberization, cell division, cytomorphogenesis and even defense against insects, pathogens and wounding (Facchini*et al*, 2002).

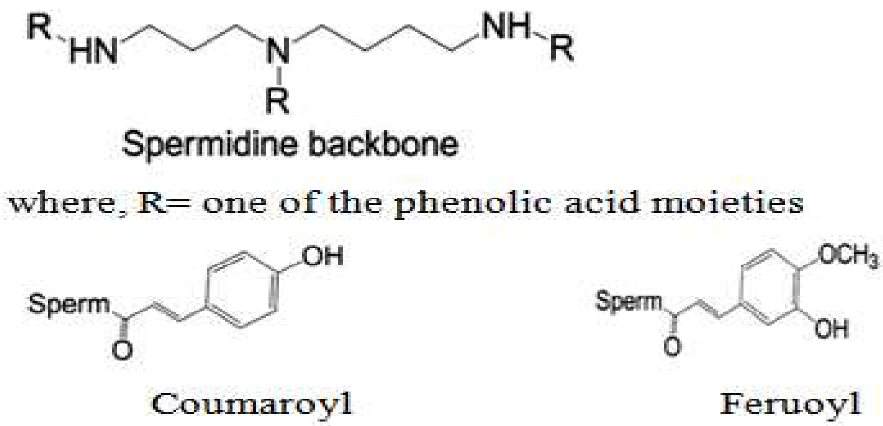

Figure 5: Structure of Spermidine Found in Tea Flowers.

Gene Expression with Bioactivity of Tea Flowers

The process of flower induction and development involves an intricate physiological process comprising of numerous endogenous as well as extraneous factors (Liu *et al*, 2017). During the past decade, molecular and genetic mechanisms involved in tea flower induction, differentiation and development have been inferred. Floral induction has been found to be influenced by the expression of genes such as gibberellic acid intensive dwarf 1B (GID1B) and GID1C, gibberrelin 3-oxidase 1 (GA3ox1), GIGANTEA (GI), pseudo-response regulator (PRR7) and flowering locus T (FT), whereas expression of genes such as leafy (LFY), pound-floolish (PNF) and pennywise (PNY) were correlated with floral bud formation (Liu *et al*, 2020). 207 unigenes and transcription factors such as WRKY, ERF, MYB, bHLH and MADS-box have been particularly identified with flowering-associated roles in tea (Liu *et al*, 2017).

Tea flower differentiation and development includes various processes. The tubulin-encoding *Tua1* and pollen coat protein (*Pcp*) genes have been observed to promote pollen tube growth (Fang et al, 2006) and anther development (Ye *et al*, 2008) in tea. Pollen tube elongation in tea flowers is also regulated via the nitric oxide (NO) pathway under low temperature stress by the CAMTA TFs, COBRA-like genes and phosphatidylinositol-4-kinase (PI4K) (Pan *et al*, 2016).

Moreover, major genes responsible for total catechin content in tea flowers such as chalcone synthase (CH2) and flavonol synthase (FLS) were found to be highly expressed during early flowering stage, while genes such as phenylalanine ammonia lyase (PAL1) and flavonoid 3'-hydroxylase (F3'H1) were expressed in the late flowering stage and negatively correlated with the total catechins content in the flowers (Sun *et al*, 2019). As is evident, aroma compound formation during tea flowering increases. This occurs due to the increasing activity of hydrolytic enzymes such as glycosidases (Watanabe *et al*, 1993; Hayashi *et al*, 2004). Consequently, flavor precursors formed during anthesis are converted to volatile compounds leading to the gradual development of unique odors (Watanabe *et al*, 1993).

CONCLUSION

Tea flowers have been used as deodorizer, skin care, flavoring agent, etc in China and Japan for centuries. However, in the last two decades, the presence of health-beneficial bioactive molecules in tea flowers has been globally acknowledged. Tea flowers, earlier regarded as waste, are now being increasingly used as an additive in health drinks and various other beverages. In an initial study, tea flower extracts have also been found to be non-mutagenic and non-toxic. Nevertheless, comprehensive research on tea flowers needs to be carried out to decipher the restrictive factors, if any, in their commercial use. Ideal plucking procedures need to be devised as flowers often undergo browning easily due to the high concentration of moisture and polyphenol oxidases. Moreover, optimal extraction procedures of the individual biomolecules from tea flowers also need to be developed targeting their specific uses.Tea flowers, thus, provide an avenue of applied research with extensive potential in pharmaceutical, cosmetic and food industry.

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