Deterioration of Tea Quality Caused by Tea White Scab Disease Disease

Ling-yun Zhou (✉ hncyszly@hunaas.cn)  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Wen-bo Yang  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Wei Li  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Hong-yan Liu  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Fen Xiang  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Xia Yin  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Ze-xuan Zeng  
Tea Research Institute, Hunan Academy of Agricultural Sciences

Research Article

Keywords: Tea, Tea white scab disease, Sensory quality evaluation, Amino acids

DOI: https://doi.org/10.21203/rs.3.rs-149881/v1

License: ☕️ ☀️ This work is licensed under a Creative Commons Attribution 4.0 International License.  Read Full License
Abstract

Tea is a popular daily beverage worldwide, especially in China. Tea white scab disease affects tea quality is poorly understood. In the current study, we aimed to determine whether tea quality will vary. We collected green tea samples from five samples (with varying morbidity from CK to Ⅲ) on Baiyun Mountain in Hunan Province. Results showed that tea quality are obviously decreased as infected by tea white scab disease. Results showed that an increase in incidence rate decreased total tea polyphenols (TP), water extract and caffeine but increased amino acids (AA). Nonetheless, the constituents of polyphenolic compounds were differentially altered. Additionally, the percentage of (−)-epicatechin (EC) and (−)-epicatechin-3-gallate (ECG) increased with increasing morbidity. (−)-epigallocatechin (EGC) and (−)-epigallocatechin-3-gallate (EGCG) just the opposite. The constituents of AA, especially Alanine, γ-aminobutyric acid, serine and phenylalanine increased with increasing elevational gradients. Proline, and theanine were reduced along with morbidity level. As a whole, this observation demands development of effective measures for sustaining green tea quality in the face of tea white scab disease.

1. Introduction

Tea, which made from the fresh leaves of tea plant (Camellia sinensis), is one of the mostly used daily beverage throughout the world, especially in China. It is estimated that more than 3 billion cups of tea are consumed every day (L. Chen & Zhou, 2005; Z. Chen, 1994). Tea also is associated with many physiological and pharmacological health benefits (Singh, Shankar, & Srivastava, 2011). Back to 2737 B.C., China is the earliest country for cultivation and utilization of tea plant, and South China are the main area (Hasimoto M, 1978; Yamanishi, 1995). As vital economic crop in South China, tea white scab could attach enough importance.

Tea white scab disease, which are important to susceptible tea cultivars are grown in humid areas, can cause tea leaves blemishes. This disease not only can reduce the quality of tea for the market, but also cause tea yield losses. Fungal pathogens Elsinoe leucospila are initiated when spores attach to host surfaces and germinate (Hématy, Cherk, & Somerville, 2009; Underwood, 2012; Zhou, et al., 2020). Then the spores breach external and internal barriers with altering host defence mechanisms and establish biotrophic interactions (Tucker & Talbot, 2001), and usually cause external blemishes, tea white scab disease. This organism can affect the leaves and twigs on many susceptible cultivars, such as lemons, grapefruit, and many tangerines (K. R. Chung, 2011; Paudyal, Hyun, & Hwang, 2017). For infecting tea leaves, there were no report in South China.

As health benefits drink, the basic components of tea like catechins, alkaloids, proteins and carbohydrate were potential health benefits (Banerjee & Chatterjee, 2015). At the same time, the function of the tea is also largely attributed to the abundant secondary metabolites (Hamiltonmiller, 2001; Lv, Zhu, et al., 2015). For example, flavonols, anthocyanins, saponin, and aroma precursors (Lv, Dai, et al., 2015; Wu, Xu, Héritier, & Andlauer, 2012). It is know that catechin, caffeine content and sensory attributes determines the quality of tea (Choung & Lee, 2011). Thus, evaluating variations in tea composition effect by Tea white scab disease is necessary.
2. Material And Methods

2.1 Sample Collection

From January 2015 to January 2019, Sampling was conducted from five levels with varying morbidity including CK (morbidity: 0),  (morbidity: 11–40%),  (morbidity: 41–50%),  (morbidity: 51–80%),  (morbidity: 81–100%), which were leaves of fuding white tea variety of 17 years with the same management from the cities of changde in Hunan in China. All the samples were split into two, one batch was Baked sample immediately and the other batch left to pan-fired for different durations.

2.2 Determination of sensory quality evaluation

According to the national standard (GB/T 23776 − 2009), the samples of pan-fired tea were put into 90°C water with the proportion by tea and water is 1:50, appearance(a), aroma(b), Liquor color(c), taste(d) and Infused leaves(e). The scoring factors and coefficients are shown in Table 1. The total score of each factor is 100 points, Sensory evaluation = a×25%+b×10%+c×25%+d×30%+e×10%.

| Level | Appearance | Aroma | Liquor color | Taste | Infused leaves | Total |
|-------|------------|-------|--------------|-------|----------------|-------|
| CK    | Tight, green, smooth | 88 | Clean and high aroma | 90 | Brilliant green | 90 | Fat and tender | 90 | 90 |
| 1     | Tight, green, smooth | 88 | Clean and high, with little smell | 88 | Brilliant green, light yellow | 89 | Sweet and mellow, slight bitter | 88 | Fat and tender, little spots | 88 | 88 |
| 2     | Tight, yellowish green, smooth | 88 | Clean aroma, with smell | 88 | Brilliant green, deep yellow | 89 | Slight bitter | 85 | Fat and tender, clear spots | 86 | 87 |
| 3     | Coarse, yellowish green, flat and thin | 85 | Without aroma, with smell | 86 | Yellow green dull, deeply | 88 | Heavy bitter, astringency | 80 | Tender yellow, Spots | 85 | 84 |
| 4     | Coarse, yellowish green, tea dust | 80 | Without aroma, with heavy smell | 82 | Yellow green, deeply | 85 | Heavy bitter, astringency | 75 | Tender yellow, Spotted densely | 83 | 80 |

Note: CK (morbidity: 0),  (morbidity: 11–40%),  (morbidity: 41–50%),  (morbidity: 51–80%),  (morbidity: 81–100%)
2.3 Determination of basic biochemical component test

We detected water extract of tea, free amino acids, caffeine, tea polyphenols, and flavonoids. Ethanol was used as a solvent to extract phenolic compounds from dried fresh tea samples. The extraction was performed at temperature of 40, 50, and 60°C which was maintained using a water bath. Folin-Ciocalteu's reagent was used to determine the total phenolic content spectrophotometrically and gallic acid was used as the calibrant (Komes, et al., 2010). Briefly, the diluted sample extract (1.0 ml) was transferred to tubes in duplicate, where each tube contained 5.0 ml of a 1/10 dilution of Folin–Ciocalteu's reagent in water.

2.4 Determination of catechin and monomer content

We carried out further phytochemical analysis to determine concentrations of individual catechins and free amino acid compounds from a sub-sample of tea samples. An HPLC method (GB/T 8313-2008) was used to quantify concentrations of catechins as described by (Wei, et al., 2011). The individual catechins we measured include: epigallocatechin-3-gallate (EGCG), epicatechin gallate (ECG), epigallocatechin (EGC) and epicatechin (EC).

2.5 Determination of Amino acids composition

An automatic amino acid analyzer (Hitachi L-8900, Japan) was used to measure individual amino acids including Proline, Alanine, Methionine, Tyrosine, β-alanine, Tryptophan, α-Aminobutyric acid, Arginine, Theanine, Glutamic acid, Phenylalanine, Phosphoserine, Taurine, Phosphoethanolamine, Urea, Aspartic acid, Threonine, Serine, Asparaginate, Glycine, Citrulline, Valine, Cystine, Isoleucine, Leucine, β-Aminoisobutyric acid, γ-Aminobutyric acid, Histidine, Ornithine, Lysine, α-Aminoadipic acid. Amino acids were measured by adding 5 ml of tea extract with 5 ml of sulfosalicylic acid and centrifuging the mixture at 13,000 rpm for 5 min to facilitate the reaction. The mixture was filtered through a 0.20-μm nylon filter membrane and run using the amino acid analyzer (Wang, et al., 2006).

3. Results

3.1 Effect of tea white scab disease on Sensory quality evaluation

Tea made from increasingly severe tea white scab disease infected tea leave recorded a markedly progressive decline in appearance, aroma), Liquor color, taste and Infused leaves (Table 1). Along with the increase of morbidity (from CK to ), the appearance were from tight, green, smooth to coarse, yellowish green, and tea dust were increased. The aroma also with heavy smell. For liquor color, the CK were brilliant green, but turn into deep yellow green. The taste were obvious difference which changed from sweet and mellow to heavy bitter. At last, we had found densest spots on leave  tea infused leaves.

3.2 Effect of tea white scab disease on Basic biochemical component
As four conventional index, water extract, caffeine and tea polyphenols were markedly decreased when the tea quality change. Free amino acids and flavonoids were fluctuate (Table 2).

| Level | Water extract | Free amino acids | Caffeine | Tea polyphenols | Flavonoids |
|-------|---------------|------------------|----------|----------------|------------|
| CK    | 42.14 ± 5.51a | 3.34 ± 0.87a     | 2.92 ± 1.23a | 25.51 ± 4.09a | 0.63 ± 0.06a |
| †††   | 40.56 ± 3.37a | 3.27 ± 0.67a     | 2.25 ± 0.49a | 24.83 ± 1.02a | 1.23 ± 0.21b |
| ‡‡‡   | 38.59 ± 3.44a | 3.48 ± 0.59a     | 1.67 ± 0.47a | 22.62 ± 2.66a | 0.87 ± 0.06a |
| †‡‡   | 37.62 ± 2.79a | 3.72 ± 0.24a     | 1.49 ± 0.67a | 21.99 ± 1.54a | 1.30 ± 0.10b |
| ††   | 36.59 ± 1.67a | 4.04 ± 0.43a     | 1.42 ± 0.65a | 15.63 ± 1.05b | 1.43 ± 0.12b |

Letters mean significant level (P < 0.05); Minimum detectable: 0.01mg·g

3.3 Effect of tea white scab disease on Catechin and monomer content

The variation of catechin and monomer content along with increase of tea morbidity (from CK to ††) were shown in Table 3. Catechin was the most important functional composition in tea. Obviously, it was on a declining curve, but some its monomer content (EC, ECG) were up.

| Level | Catechin | EC     | ECG    | EGC    | EGCG   |
|-------|----------|--------|--------|--------|--------|
| CK    | 13.33 ± 0.32a | 0.63 ± 0.35a | 1.38 ± 0.34a | 3.50 ± 0.24a | 6.44 ± 1.70a |
| †††   | 12.93 ± 1.16a | 0.73 ± 0.40a | 1.48 ± 0.42a | 3.07 ± 0.05ab | 6.26 ± 0.94a |
| ‡‡‡   | 11.87 ± 0.91a | 0.86 ± 0.46a | 1.62 ± 0.45a | 2.65 ± 0.30bc | 5.74 ± 1.19a |
| †‡‡   | 11.63 ± 2.25a | 1.11 ± 0.60a | 1.74 ± 0.53a | 2.61 ± 0.11bc | 5.17 ± 1.50a |
| ††   | 10.80 ± 2.35a | 1.69 ± 1.12a | 1.90 ± 0.40a | 2.12 ± 0.39c | 3.59 ± 0.85a |

(−)-epicatechin (EC), (−)-epigallocatechin (EGC), (−)-epicatechin-3-gallate (ECG),(−)-epigallocatechin-3-gallate(EGCG). Values are expressed as mg/g DW. Mean denoted by same letters are not significantly different according to Duncan's multiple range test (P< 0.05), Minimum detectable: 0.01mg·g

3.4 Effect of tea white scab disease on amino acid composition

It is known that many amino acids on tea and some were important for human. Our study revealed most amino acids variation in samples (Table 4). Among those amino acid, proline and theanine were reduce along with morbidity level. Alanine, γ-aminobutyric acid, serine, and phenylalanine were increased with increasing elevational gradients. To our interesting, tryptophan, asparagine, glutamic acid, and glycine were
increased abruptly on level Ⅲ (morbidity: 51–80%). Some amino acids such as α-aminobutyric acid, cystine had not been found on the tea severe infected by *Elsinoe leucospila* (level Ⅲ, Ⅳ). The other amino acids also have some changes.
Table 4
Amino acid composition content of tea with white scab diseases (mg·g−1)

| Amino acid profile         | CK       | Ⅱ        | Ⅲ        | Ⅳ        | Ⅴ        | Ⅵ        |
|----------------------------|----------|----------|----------|----------|----------|----------|
| Proline                    | 0.021±0.003a | 0.020±0.003a | 0.005±0.005b | 0.000b   | 0.000b   |
| Alanine                    | 0.003±0.003a | 0.012±0.011ab | 0.014±0.002ab | 0.020±0.004ab | 0.022±0.007b |
| Methionine                 | 0.001±0.002a | 0.008±0.007ab | 0.021±0.013b | 0.007±0.002ab |
| Tyrosine                   | 0.026±0.009a | 0.007±0.006b | 0.012±0.001b | 0.009±0.001b | 0.011±0.002b |
| β-alanine                  | 0.003±0.005a | 0.005±0.009a | 0.018±0.007a | 0.022±0.002a | 0.011±0.007a |
| Tryptophan                 | 0.102±0.024a | 0.081±0.032ab | 0.054±0.009ab | 0.066±0.029ab | 0.027±0.015b |
| α-Aminobutyric acid        | 0.000a     | 0.005±0.008a | 0.009±0.008a | 0.000a   | 0.000a   |
| Arginine                   | 0.007±0.005a | 0.015±0.014a | 0.033±0.003a | 0.061±0.043a | 0.320±3.791a |
| Theanine                   | 1.334±0.116a | 1.030±0.022a | 1.017±0.076a | 0.796±0.112a | 0.527±0.116a |
| Glutamic acid              | 0.222±0.014a | 0.193±0.032a | 0.165±0.013a | 0.298±0.209a | 0.194±0.024a |
| Phenylalanine              | 0.006±0.010a | 0.000b    | 0.001±0.001ab | 0.002±0.001b | 0.003±0.001ab |
| Phosphoserine              | 0.009±0.000a | 0.011±0.001a | 0.010±0.001a | 0.028±0.031a | 0.012±0.002a |
| Taurine                    | 0.012±0.002a | 0.001±0.000b | 0.002±0.002b | 0.001±0.001b | 0.002±0.001b |
| Phosphoethanolamine        | 0.027±0.006a | 0.029±0.017a | 0.010±0.009a | 0.010±0.009a | 0.013±0.002a |
| Urea                       | 0.250±0.150a | 0.061±0.106a | 0.204±0.178a | 0.259±0.290a | 0.249±0.082a |
| Aspartic acid              | 0.143±0.026a | 0.110±0.033a | 0.09±0.005a | 0.172±0.129a | 0.028±0.017a |
| Threonine                  | 0.028±0.008a | 0.026±0.011a | 0.018±0.004a | 0.040±0.034a | 0.021±0.002a |
| Serine                     | 0.089±0.027a | 0.094±0.050a | 0.098±0.017a | 0.129±0.141a | 0.147±0.007a |

Letters mean significant level (P < 0.05); Minimum detectable: 0.01 mg·g−1
### 4. Discussion

Tea is a significant aquaculture species in China (Y. F. Li, et al., 2017). Tea white scab disease were found to occur at varying levels in tea. Consumer acceptability of tea greatly depends upon its sensory quality evaluation. Tea quality depends upon spatiotemporal variability of geographical origin, manufacturing process, which in turn highly influence the chemical composition, and which are very critical in determining its quality. On the other hand, sensory quality evaluation factors like color, appearance, flavor and taste also determines its commercial value (Bhattacharyya, et al., 2012; Bhondekar, et al., 2010). Qin et al (2017) compared the difference on sensory quality evaluation by human panel test and spectroscopy system, and revealed the variation on tea from different areas and variety. As shown in Table 1, tea white scab seases can strongly effect on the tea in sensory quality evaluation. The characteristic of high quality tea (CK) were
green, smooth appearance; clean, high aroma; sweet, mellow taste, and fat, tender infused leaves. but the
diseased one were quite another thing. Sensory quality evaluation, as first tea standard of National Food
Safety Standards of China, is important for appraisaling tea quality. The effect of Tea white scab disease
could be paid attention to.

Aqueous extract, caffeine, tea polyphenols, and flavonoids were the significant component in tea (P. Li,
Wang, Ma, & Zhang, 2005). The tea polyphenols content in tea are about 28.4%, and be proved the more and
more important functions, such as antimutagenic activity, antioxidant activity, depressor effect on renal
hypertension, inhibitory effect on lipid peroxidation, and inhibitory effect on arteriosclerosis (L. Chen & Zhou,
2005; Z. Chen, 1989; Yamamoto, Juneja, Chu, & Kim, 1997). Caffeine makes a significant contribution to the
briskness and creaming properties of tea brew, Its average content was about 4.2%. When on the low-
caffeine tea, it will lose special tea aroma and taste (L. Chen & Zhou, 2005; Willson & Clifford, 1992).
Flavonoids are the main regulators of plant growth and defense, and also contribute to the color, taste and
aroma of tea (Jay-Allemand, Tattini, & Gould, 2015; Q, M, & J, 2017). Our result show caffeine, tea
polyphenols and water extract were dramatic decline. It is agree with the previous report about the tea
influence by Tea white scab disease (Zhou, Deng, & Deng, 2007). We believe that Tea white scab disease in
tea can damage basic biochemical component on tea.

Tea polyphenols are mainly composed of five catechins and their derivatives. Epigallocatechin gallate
(EGCG) is the largest portion, next epigallocatechin (EGC), epicatechin gallate (ECG), epicatechin (EC),
gallocatechin (GC), respectively(L. Chen & Zhou, 2005). As a marker for superior quality in tea, catechins
index is very important(Magoma, Wachira, Obanda, Imbuga, & Agong, 2000). Fan et al (2016) show
difference thermal processing can cause variation in tea catechins. Our study also uncover the tea catechins
content change along with tea white scab disease. Tea contain high levels of amino acids, the profile of
which beneficial health effects have also been proposed (Bryan, 2008). Good quality teas require high
concentrations of amino acids principally contributing to mellowness and freshness, and an optimum ratio
of amino acids for a balance of astringent to mellow tastes (Wang, Cheng, Yuchen, & Liu, 1988). It consistent
with our results that many amino acids varied along with the increase of morbidity (from CK to δ).

In conclusion, the present study showed the new pathogen (Elsinoe leucospila) of Tea white scab disease in
tea from south China and comprehensive analysis the tea quality along with the increase of morbidity (from
CK to δ). In our study, sensory quality evaluation, basic biochemical component, catechin and monomer
content and amino acid composition of tea are obvious change after infected by tea white scab disease.
Thus, the result will give advice to farm operators to understand and control Tea white scab disease in tea.

Declarations

Acknowledgments

This work was supported by the National Key Research and Development Plan (Project No.
2016YFD0200904), the Hunan Key Research and Development Plan (Project No. 2018NK2033), and the
National Natural Science Foundation of China (Project No. 31272012)
Compliance with ethical standards

Conflicts of interest All authors declare no conflicts of interest.

Compliance with ethics requirements This article does not contain any studies with human or animal subjects.

References

1. Anonymous (2005) ISO 14502-1: 2005. Determination of substances characteristic of green and black tea. Part 1: content of total polyphenols in tea. Colorimetric method using Folin–Ciocalteu reagent.

2. Anesini C, Ferraro GE, Filip R (2008) Total polyphenol content and antioxidant capacity of commercially available tea (Camellia sinensis) in Argentina. J Agric Food Chem 56(19):9225–9229.

3. Banerjee, S., & Chatterjee, J. (2015). Efficient extraction strategies of tea (Camellia sinensis) biomolecules. Journal of Food Science and Technology, 52(6), 1-11.

4. Bhattacharyya, R., Tudu, B., Das, S. C., Bhattacharyya, N., Bandypadhyay, R., & Pramanik, P. (2012). Classification of black tea liquor using cyclic voltammetry. Journal of Food Engineering, 109(1), 120-126.

5. Bhondekar, A. P., Dhiman, M., Sharma, A., Bhakta, A., Ganguli, A., Bari, S. S., Vig, R., Kapur, P., & Singla, M. L. (2010). A novel iTongue for Indian black tea discrimination. Sensors & Actuators B Chemical, 148(2), 601-609.

6. Bryan, J. (2008). Psychological effects of dietary components of tea: caffeine and L-theanine. Nutrition Reviews, 66(2), 82.

7. Carbone, I., & Kohn, L. M. (1999). A Method for Designing Primer Sets for Speciation Studies in Filamentous Ascomycetes. Mycologia, 91(91), 553-556.

8. Chen, L., & Zhou, Z. X. (2005). Variations of main quality components of tea genetic resources [Camellia sinensis (L.) O. Kuntze] preserved in the China National Germplasm Tea Repository. Plant Foods for Human Nutrition, 60(1), 31.

9. Chen, Z. (1989). Tea Production in China and Therapeutic Effect of Tea. In SFA-ISAPP 2011 conference (pp. 628-630).

10. Chen, Z. (1994). Prospect on Tea Industry in the Year of 2000. Journal of Teaence.326.12

11. Choung, M. G., & Lee, M. S. (2011). Optimal extraction conditions for simultaneous determination of catechins and caffeine in green tea leaves. Food Science and Biotechnology, 20(2), 327-333.

12. Fan, F. Y., Shi, M., Nie, Y., Zhao, Y., Ye, J. H., & Liang, Y. R. (2016). Differential behaviors of tea catechins under thermal processing: Formation of non-enzymatic oligomers. Food Chemistry, 196, 347-354.

13. Hématy, K., Cherk, C., & Somerville, S. (2009). Host-pathogen warfare at the plant cell wall. Current Opinion in Plant Biology, 12(4), 406-413.

14. Hamiltonmiller, J. M. (2001). Anti-cariogenic properties of tea (Camellia sinensis). Journal of Medical Microbiology, 50(4), 299-302.
15. Hasimoto M, T. S. (1978). Morphological Studies on the Origin of the Tea Plant: V. A proposal of one place of origin by cluster analysis. *Jpn J Trop Agric*, 21, 93-101.

16. Hyun, J. W., Yi, S. H., Mackenzie, S. J., Timmer, L. W., Kim, K. S., Kang, S. K., Kwon, H. M., & Lim, H. C. (2009). Pathotypes and genetic relationship of worldwide collections of *Elsinoë* spp. causing scab diseases of citrus. *Phytopathology*, 99(6), 721.

17. Jay-Allemand, C., Tattini, M., & Gould, K. S. (2015). New evidence for the functional roles of secondary metabolites in plant–environment interactions: Special issue of Environmental and Experimental Botany (EEB). *Environmental & Experimental Botany*, 119(1), 1-3.

18. JC, W. (1979). *Fungal identification manual*. Shanghai Scientific and Technical Publishers.

19. Jenkins, A. E., & Bitancourt, A. A. (1946). Two scab diseases of tea, caused by *Elsinoe leucospila*, and their distribution. *Archivos Do Instituto Biologico Sao Paulo*, 67-72.

20. Komes D, Horžić D, Belščak A, et al. Green tea preparation and its influence on the content of bioactive compounds. *Food research international*, 2010, 43(1): 167-176.

21. Li, P., Wang, Y., Ma, R., & Zhang, X. (2005). Separation of tea polyphenol from Green Tea Leaves by a combined CATUFM-adsorption resin process. *Journal of Food Engineering*, 67(3), 253-260.

22. Li, Y. F., Ouyang, S. H., Chang, Y. Q., Wang, T. M., Li, W. X., Tian, H. Y., Cao, H., Kurihara, H., & He, R. R. (2017). A comparative analysis of chemical compositions in *Camellia sinensis* var. puanensis Kurihara, a novel Chinese tea, by HPLC and UFLC-Q-TOF-MS/MS. *Food Chemistry*, 216, 282-288.

23. Lingyun Z, Yunfeng L, Chunyan J, et al. Identification of the pathogen responsible for tea white scab disease. *Journal of Phytopathology*, 2017, 168(1): 28-35.

24. Lv, H. P., Dai, W. D., Tan, J. F., Guo, L., Zhu, Y., & Lin, Z. (2015). Identification of the anthocyanins from the purple leaf coloured tea cultivar Zijuan (*Camellia sinensis* var. assamica) and characterization of their antioxidant activities. *Journal of Functional Foods*, 17(9612), 449-458.

25. Lv, H. P., Zhu, Y., Tan, J. F., Guo, L., Dai, W. D., & Lin, Z. (2015). Bioactive compounds from Pu-erh tea with therapy for hyperlipidaemia. *Journal of Functional Foods*, 19, 194–203.

26. Magoma, G. N., Wachira, F. N., Obanda, M., Imbuga, M., & Agong, S. G. (2000). The use of catechins as biochemical markers in diversity studies of tea (*Camellia sinensis*). *Genetic Resources and Crop Evolution*, 47(2), 107-114.

27. Ouyang, Q., Liu, Y., Chen, Q., Zhang, Z., Zhao, J., Guo, Z., & Gu, H. (2017). Intelligent evaluation of color sensory quality of black tea by visible-near infrared spectroscopy technology: A comparison of spectra and color data information. *Spectrochimica Acta Part A Molecular & Biomolecular Spectroscopy*, 180, 91.

28. Paudyal, D. P., Hyun, J. W., & Hwang, R. Y. (2017). Infection and symptom development by citrus scab pathogen *Elsinoë fawcettii* on leaves of satsuma mandarin. *European Journal of Plant Pathology*, 1-10.

29. Q, Z., M, L., & J, R. (2017). Metabolomics analysis reveals the metabolic and functional roles of flavonoids in light-sensitive tea leaves. *BMC Plant Biology*, 17(64), 1.

30. S, T., & T, F. (1976). White star on tea fungus forming method for large amount of culture. *Annals of the Phytopathological Society of Japan*, 42.
31. Singh, B. N., Shankar, S., & Srivastava, R. K. (2011). Green tea catechin, epigallocatechin-3-gallate (EGCG): mechanisms, perspectives and clinical applications. *Biochemical Pharmacology, 82*(12), 1807.

32. Tucker, S. L., & Talbot, N. J. (2001). Surface attachment and pre-penetration stage development by plant pathogenic fungi. *Annual Review of Phytopathology, 39*(1), 385.

33. Underwood, W. (2012). The Plant Cell Wall: A Dynamic Barrier Against Pathogen Invasion. *Frontiers in Plant Science, 3*(85), 85.

34. Wang, Y., Cheng, Q., Yuchen, R., & Liu, W. (1988). Discussion on the Chemical Standards on Quality of Chinese Roasted Green Tea. *Journal of Tea Science, 8*(8), 13-16.

35. Wang, H. F, Tsai, Y. S, Lin M L, et al. Comparison of bioactive components in GABA tea and green tea produced in Taiwan. *Food chemistry, 2006, 96*(4): 648-653.

36. Wei, K, Wang L, Zhou J, et al. Catechin contents in tea (Camellia sinensis) as affected by cultivar and environment and their relation to chlorophyll contents. *Food chemistry, 2011, 125*(1): 44-48.

37. White, T. J., Bruns, T. D., Lee, S. B., Taylor, J. W., Innis, M. A., Gelfand, D. H., & Sninsky, J. J. (1990). Amplification and Direct Sequencing of Fungal Ribosomal RNA Genes for Phylogenetics *PCR Protocols, 315-322.*

38. Willson, K. C., & Clifford, M. N. (1992). Tea: cultivation to consumption: *Chapman & Hall, 175–182.*

39. Wu, C., Xu, H., Héritier, J., & Andlauer, W. (2012). Determination of catechins and flavonol glycosides in Chinese tea varieties. *Food Chemistry, 132*(1), 144-149.

40. Yamamoto, T., Juneja, L. R., Chu, D. C., & Kim, M. (1997). Chemistry and applications of green tea. *Chemistry & Applications of Green Tea, 1,*1

41. Yamanishi, T. (1995). Flavor of tea. *Food Reviews International, 11, 477-525.*

42. Zhou, L., Deng, X., & Deng, K. (2007). White tea disease impact on fresh tea leaves about main chemical components *Journal of hunan agricultural university (since), 33*(6), 741-743.