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Research Article

Evaluation of various Chinese green teas for sensory mapping and chemical composition

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Abstract

A systematic study was carried out on 8 popular Chinese green teas on their sensory profile and chemical composition in the tea leaves and infusion. Using descriptive analysis, a total of 47 sensory attributes, namely 15 aroma, 18 taste, 4 colour and 1 mouth feel, 9 after taste, were generated. Combination of green tea note with slight bitterness and subtle astringency was assumed as the characteristic taste of Chinese green tea. The relationship between taste attributes and the concentration of major components in tea infusion was also investigated. The taste constituents, including EGCG, amino acid, caffeine, contribute to green tea taste dramatically that reflects to astringency mixed with bitterness.

Keywords: beverage, *Camellia sinensis*, sensory evaluation, principal component analysis (PCA), geographical variation, polyphenols, amino acids, catechins.

Introduction

Green Tea originates in China and has become associated with various beneficial health properties, and is also valued for its flavour and appearance. China has at least hundreds of well-known varieties of green teas having various sensory profiles. In general, green tea has a fresh taste, a yellowish green colour and green, roasted and smoky type of aroma. However, the chemical composition varies with manufacture processing and genetic makeup of the clone. The amount of main chemicals in end cup are the important parameters for determining the acceptance of consumers and being reflected in its market prices [1, 2]

Green tea contains polyphenols, amino acid, caffeine, which are responsible for health benefits, as well as taste profiles [3, 4, 5, 6, 7]. However, there were few investigations previously on the sensory mapping and typical taste discrimination among the varieties of Chinese green teas and the relationship between various taste notes and chemical composition has not been established yet.

Thus the main objectives of the present study were: (i) to select the representative Chinese green teas and sensory mapping by trained panel; (ii) to analyze chemical properties of each sample, including total polyphenols (TP), total catechins (TC), and amino acid (AC) etc. and (iii) to reveal the linkage of inherent taste contributors and common taste attributes using multivariate statistical analysis.

Materials and Methods

Samples

According to geography and process of Chinese green tea, fifteen Chinese green teas were purchased from local market, 9 out of 15 samples were manufactured in South of Yangzte River tea growing area, including Dongting Biluchun, Xihu Longjing, Lushan Yuwu, Anji Baicha, Liuan Guanpian, Taiping Houkui, Huangshan Maofeng, Kaihua Longding and Guzhu Zisun; 4 tea samples (namely Kuding cha, Mengding Ganlu, Duyu Maojian and Shichuan Zuoyeqing) from South-west of China tea growing area and 1 sample (Xiyang Maojian) from North of China and 1 sample (Enshi Yulu) from South of China.

All selected teas were grouped by trained sensory panelists. The individual sensory notes were discussed within the panel. Based on their origin, sensory profiles and commercial availability, 8 green teas, including Dongting Biluchun (BLC), Xihu Longjing (WLJ), Anji Baicha (AJW), Liuan Guanpian (LGP), Huangshan Maofeng (HMF), Guzhu Zisun (GZS), Shichuan Zuoyeqing (SCZ) and Enshi Yulu (NYL), were selected finally and purchased at the same grade level (Shown in Table 1) for further sensory mapping and chemistry analysis.

Sample preparation

Freshly boiled, distilled water 200 ml was poured onto 4 g dry tea leaves for 3 min brewing, stirring 3 circles clockwise with porcelain and then filtered through sieve before serving to the panelists.

Assessment of sensory attributes

Sensory panel

Twelve female panelists in an age group of 25 to 45 participated in this study. They were selected based on their sensory acuity and were trained to characterize products in terms of perceived attributes and intensities, including scoring the intensity of all attributes according to some scale references, comparing intensities of all attributes relative to each other.

Sensory attributes evaluation

The 12 trained panelists were served 50 ml of each tea infusion in plastic bowl. All taste attributes were generated and assessed with help of Fizz software, a mean score was calculated for every taste attribute on each tea sample. The final list of 47 attributes (4 appearance, 15 aroma, 1 mouth feel, 18 taste and flavour, 9 aftertaste) and their definitions are shown in Table 2.

Table 1. Green tea samples selected.

Green tea name	Sample	Producing-area	Price (RMB/kg)	Process
Dongting Biluochun	BLC	Jiangsu	960	Pan frying
Xihou Longjin	WLJ	Zhejiang	960	Pan frying
Anji Baicha	AJW	Zhejiang	1000	Pan frying-baking
Sichuang Zhuyeqing	SCZ	Sichuan	1000	Pan frying
Liuan Guanpian	LGP	Anhui	1300	Baking
Huangshan Maofeng	HMF	Anhui	1300	Baking
Enshi Yulu	NYL	Hubei	720	Steaming
Guzhu Zisun	GZS	Zhejiang	1900	Pan frying-baking

Determination of major taste components

Tea polyphenol (TP), total catechins (TC), amino acid (AA) and caffeine are known to be predominantly responsible for the characteristic green tea taste in terms of astringency and bitterness; on the other hand, the concentrations of TP, TC and AA in the tea leaves are the reliable parameters for tea quality assessment. These four components were determined on nine Chinese teas. Water extract was also analyzed to know the molecular basis of each tea leaf.

Determination of soluble solids (SS) in tea infusion

Tea infusion was prepared by 4 gm tea brewed in 200 ml boiled water for 3 minutes. After filtration, the tea infusion was lyophilized by freeze-drier. The solid was weighed for the calculation of soluble solids.

Determination of total polyphenols in tea leaves and tea infusion

Total polyphenol contents in tea and tea infusion were determined by a colorimetric assay using Folin-Ciocalteu phenol reagent with gallic acid as standard according to a method specified by the International Standard (ISO 14502-1).

Determination of free amino acids in tea leaves and tea infusion

For tea leaves, free amino acids were extracted by methanol/water (70/30, v/v) at 70°C. Then the extracts were sent to a contract lab and analyzed by amino acid analyzer following GB 5009.124-2003. The samples of tea infusion were sent to a contract lab without pre-treatment and analyzed by amino acid analyzer following GB 5009.124-2003.

Determination of theanine in tea leaves and tea infusion

Weigh (1.00 ± 0.01) g of tea leaves in a 200 mL beaker and add 100 mL of boiling water. Allow to brew for 5 min on a magnetic stirrer (500 upm) and filter. Let the tea brew cool down, make up to volume and 1 ml of the sample solution can be centrifuged at 13,000 rpm for 10 min prior to UPLC-

UV analysis [8]. The samples of tea infusion were analyzed without pretreatment by same UPLC-UV method.

Determination of catechins and caffeine in tea leaves and tea infusion

Catechins and caffeine in tea and tea infusion were determined by HPLC according to a method specified by the International Standard (ISO 14502-2).

Determination of water extract in tea leaves

The determination of water extract was conducted according to the method specified by international Standard (ISO 9768).

Table 2. Forty-seven sensory attributes and definition.

Group	Attributes	Definition
Aroma	Overall Strength	The overall strength of aroma perceived in sample
	Chestnut	The aroma associated with cooked chestnut
	Green tea	The aroma associated with green tea
	Grass	The aroma associated with fresh grass
	Floral	The aroma associated with mixed floral
	Reed leaf	The aroma associated with cooked reed leaf
	Fried	The aroma associated with fried tea leaf
	Smoke	The aroma associated with smoked ham
	Cigarette	The aroma associated with odor of cigarette
	Soybean milk	The aroma associated with soybean milk
	Fried soybean	the degree of aroma associated with fried soybean
	Cooked vegetable	the aroma associated with cooked vegetable, chrysnathemum greens
	Coolness	the degree of aroma associated with coolness, refreshment
	Hay	the aroma associated with hay
	Fishy	the aroma associated with fishy, tea leaf, mulberry leaf
Appearance	Green	the degree of green colour in sample
	Yellow	the degree of yellow colour in sample
	Brightness	the degree of brightness in sample
	Cloudiness	the degree of cloudiness of sample

Group	Attributes	Definition
Taste & Flavor	Overall Strength	The overall strength of taste perceived in sample
	Green tea	the flavour associated with green tea
	Bitterness	the basic taste of bitterness in sample
	Fried	the flavour associated with fried tea leaf
	Floral	the flavour associated with mixed floral
	Hay	the flavour associated with hay
	Coolness	the flavour associated with coolness, refreshment
	Cooked vegetable	the flavour associated with cooked vegetable, chrysnathemum greens
	Astringency	the mouth feel of astringency
	Chestnut	the flavour associated with cooked chestnut
	Grass	the flavour associated with fresh grass
	Reed leaf	the flavour associated with cooked Reed leaf
	Cigarette	the flavour associated with odor of cigarette
	Soybean milk	the flavour associated with soybean milk
	Aged	the flavour associated with tea wich is aged
	Fried soybean	the flavour associated with fried soybean
	Sweet	the basic taste of sweetness in sample
	Fishy	the flavour associated with fishy, tea leaf, mulberry leaf
MouthFeel	Thickness	the degree of thickness for mouthfeel compared with water
AfterTaste	Overall Strength	the overall taste after sample has been swallowed for 15 seconds
	Green tea	the amount of green tea flavour after sample has been swallowed for 15 seconds
	Bitterness	the amount of bitterness after sample has been swallowed for 15 seconds
	Astringency	the degree of astringency after sample has been swallowed for 15 seconds
	Sweetness	the amount of sweetness after sample has been swallowed for 15 seconds

Group	Attributes	Definition
	Chestnut	the amount of chestnut flavour after sample has been swallowed for 15 seconds
	Sourness	the amount of sourness after sample has been swallowed for 15 seconds
	Floral	the amount of floral flavour after sample has been swallowed for 15 seconds
	Coolness	the degree of coolness after sample has been swallowed for 15 seconds

Determination of reducing sugar and polysaccharides in tea infusion
The determination of reducing sugar in tea infusion was conducted according to UMA method (UMA 0759). The polysaccharides in tea infusion were determined by the phenol sulphuric acid method.

Statistical analysis
ANOVA analysis was performed to see if there were significant differences between the products ($p<0.05$) on some attributes, then a multiple comparison test was performed to determine which products were significantly different from each other. The principal component analysis (PCA) and Pearson's linear correlation were carried out by SPSS software package (SPSS 18.0 for Windows. SPSS Inc. USA).

Results and Discussion

Sensory profiles
The sensory intensities of eight Chinese teas were evaluated in the scale of 0-15 scores, for 47 attributes by a trained panel. Amongst eight green teas, almost each green tea has its own key note which differentiated from others, e.g. fried soybean for WLJ, grass for NYL, reed leaf for LGP, cooked vegetable for SCZ and soymilk for GZS. WLJ showed strongest overall aroma and taste amongst green teas; SCZ was a unique green tea with a key note of cooked vegetable in its aroma and having higher bitterness; and HMF was the weakest one on all sensory profiles.

The PCA map (dimension 1 and dimension 2, as shown in Figure 1) gave an overview of all green teas in the present study. HMF and AJW are in same group, this group is weak on most of the attributes; LGP and GZS are in medium level both on taste and aroma; WLJ, BLC and NYL are in a strong group, aroma of this group is multiple and stronger on chestnut, green tea flavour. They also show strong bitterness and astringency notes; while SCZ is isolated from other green teas with special notes of cooked vegetable and fishy, it has strongest intensity on bitterness.

Clusters of taste attributes
Considering the taste of the tea is predominantly determined by non-volatile compounds, beside colour, aroma and mouth feel, only taste attributes thus were investigated to explore the potential molecular basis of green tea taste. In total, fifteen taste attributes were defined from all the tea samples, including overall strength, green tea, bitterness, astringency, flora, cooked vegetable, chestnut, fired soybean, grass, reed leaf, soybean milk, cigarette, coolness, aged, sweet and fishy

(As shown in Figure 2). After PCA analysis, it was shown in Figure 3 that 4 of out 16 attributes, namely overall strength, green tea, bitterness and astringency, were referred to in all eight Chinese

green teas by panelists; while the other taste notes were present in different kinds of tea separately. In general, tastes like floral, chestnut, fired soybean, soybean milk and sweet, are regarded as popular tastes for green tea drinkers, while the tastes like aged, cigarette and fishy are unacceptable for consumers. However, the liking of bitterness and astringency varied depending on the country and the consumer segment, for example, the consumer in China; they generally like the green tea samples with various green tea taste and moderate bitterness.

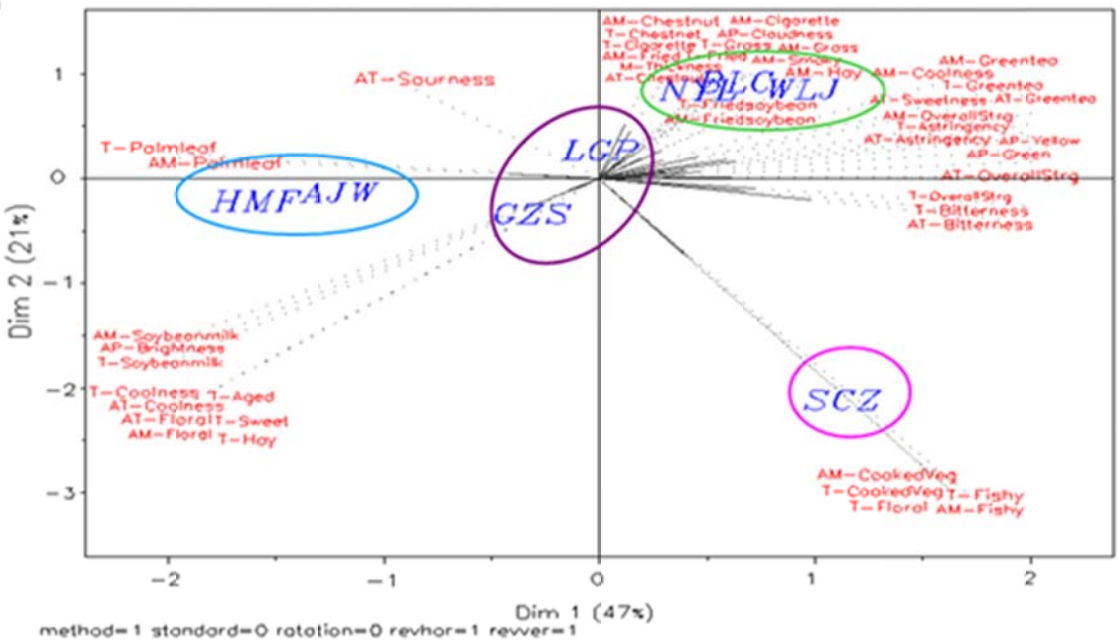

Figure 1. PCA map for sensory profile

The components were clustered by PCA so that the total sum of squares of the loadings along each new axis was maximized. The overall strength taste showed the highest communality value (0.922) in 1st component, the astringency taste was the next highest, followed by green tea taste and bitterness taste. Floral taste and coolness taste were exhibited in 2nd component. Component 3's attribute profile involved fishy taste, cooked vegetable taste, which are undesirable tastes. Grass taste, fried taste and chestnut taste, as typical Chinese green tea taste, were distributed into 4th component (As shown in Table 3).

Pearson's linear correlation analysis showed that the average score of overall strength correlated strongly with bitterness and astringency ($r = 0.986$ and 0.871 respectively, $P < 0.01$), whereas only weakly ($r = 0.831$, $P < 0.05$) with green tea taste (Table 4).

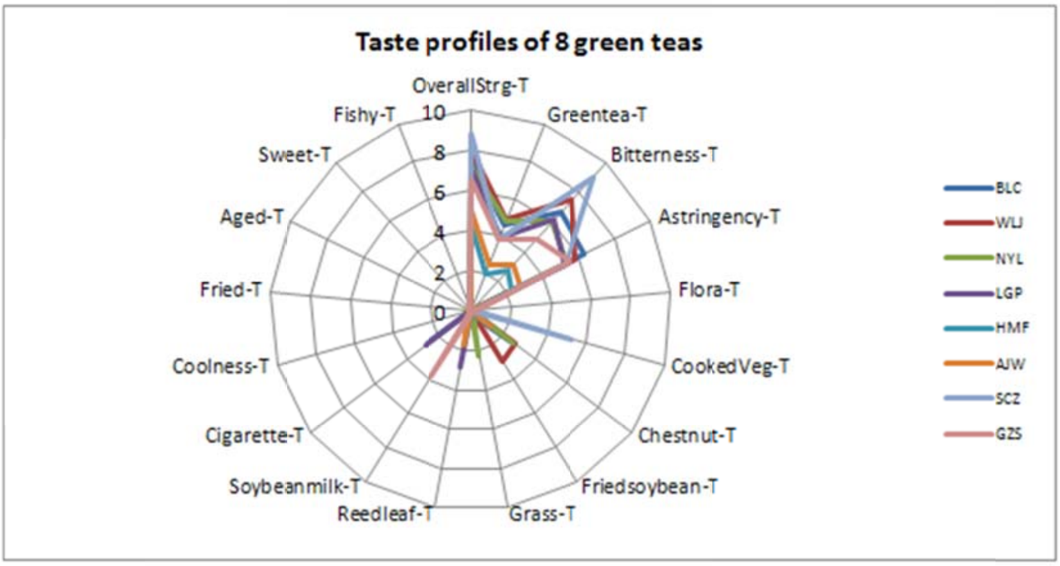

Figure 2. Sensory mapping of eight green teas.

Table 3. Components from PCA and corresponding attribute profiles.

PCA Components	Taste attributes in each cluster
1	Overall strength (0.922), Astringency (0.921), Green tea taste (0.877), Bitterness (0.858)
2	Floral taste (0.983), Coolness taste (0.981)
3	Fishy taste (0.902), Cooked vegetable taste (0.868),
4	Grass taste (0.954), Fired taste (0.875), Chestnut taste (0.619)

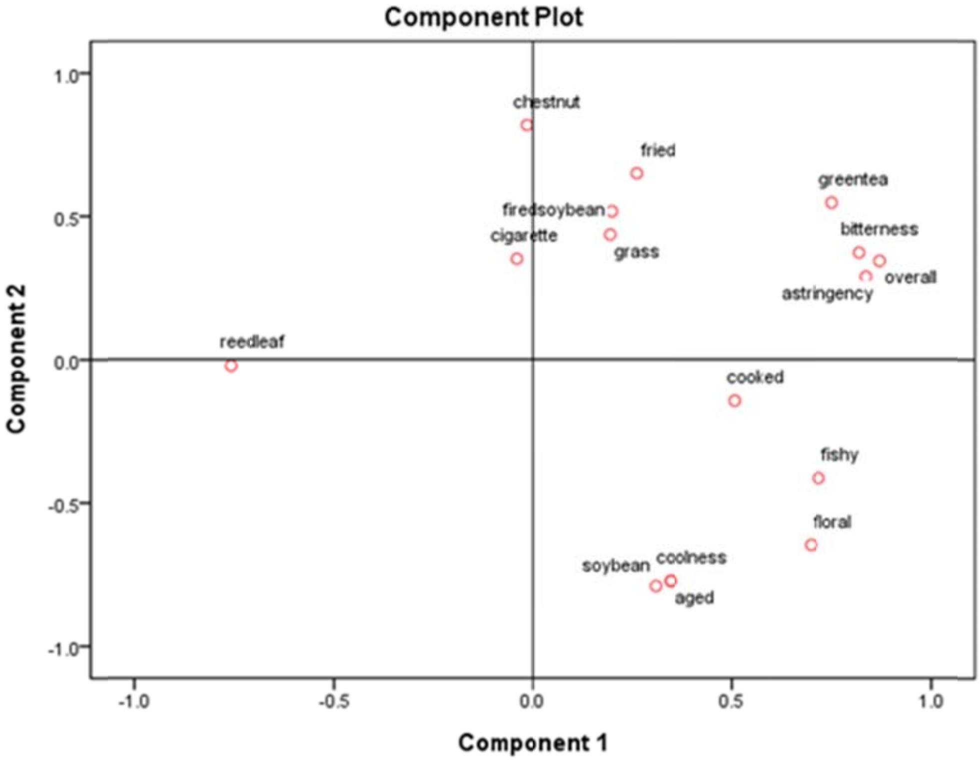

Figure 3. PCA analysis of taste attributes.

Table 4. Pearson's correlation coefficients of averaged sensory evaluation score of selected teas on attributes of overall strength, green tea taste, bitterness and astringency (tea sample no. 8).

Items	OST	GTT	BIT	AST
OST	1			
GTT	0.831*	1		
BIT	0.986**	0.760*	1	
AST	0.871**	0.934**	0.795*	1

*Correlation is significant at the 0.05 level (two-tailed)
**Correlation is significant at the 0.01 level (two-tailed)

Comparison of taste components

As illustrated in Table 5, the data of chemical analysis in each of the eight Chinese tea leaves showed similar results on the water extract and the content of TP, TC and caffeine, although they were produced by different producers and slightly different processes, there were no significant differences in major constituents among different green teas with same grade.

Table 5. Content of water extract, TP and AA, TC and caffeine in eight green teas (%).

Items	Water extract	TP	AA	TC	Caffeine
BLC	52.10±0.99	18.92±0.54	1.06±0.04	15.39±0.54	4.23±0.22
WLJ	50.80±0.21	17.32±0.56	1.25±0.08	12.48±0.62	3.97±0.20
AJW	51.10±0.64	14.7±0.38	1.28±0.06	11.85±0.19	3.28±0.10
SCZ	54.17±0.12	18.43±0.54	1.27±0.10	13.57±0.20	4.53±0.32
LGP	51.77±0.16	15.59±0.28	1.28±0.04	14.64±0.37	4.77±0.19
HMF	54.63±0.26	16.26±0.27	0.91±0.02	12.21±0.28	3.86±0.13
NYL	47.53±0.06	15.7±30	1.13±0.02	12.2±0.28	4.18±0.26
GZS	50.23±0.90	15.88±0.76	1.08±0.03	11.73±0.63	3.67±0.24
TGY	45.43±0.09	11.93±0.28	0.52±0.03	10.94±0.66	2.07±0.13

the content was expressed in Mean±SD, n=2

In contrast to the lack of component variation in the eight Chinese tea leaves, there was noticeable variation observed after 3 minutes of infusion (as shown in Table 6). HMF showed the lowest concentration of SS, TP and TC among the eight Chinese teas, followed by AJW. Furthermore, considering the variation between tea leaves and tea infusion on TP, TC and AA, more components were analyzed, such as reducing sugar and polysaccharides. It was observed that the concentrations of reducing sugar and polysaccharides in HMF were lower than other teas; however the concentration of AJW showed a similar level with other teas, which were inconsistent with the content in AJW leaves, possibly resulting from the higher extraction rate of AJW.

Tea catechins are the major components of polyphenols in tea and consist of at least eight compounds, gallocatechin (GC), epigallocatechin (EGC), catechin (C), epicatechin (EC), epigallocatechin gallate (EGCG), gallocatechin gallte (GCG), epicatechin gallate (ECG) and catechin gallate (CG). Only five compounds were detected, namely EGC, C, EC, EGCG and ECG. The concentration of EGCG of SCZ was the highest among the tested catechin compounds, followed by BLC and WLJ. In general, the major constituents of the eight tea catechins were EGCG and GC in green tea, with GC and ECG in black tea [9]. The results suggest that the green produced by pan-frying process might have higher brewing rate compared with baking process

Table 6. Concentration of SS, TP, TC and caffeine, reducing sugar and polysaccharides (mg/200ml).

Items	BLC	WLJ	AJW	SCZ	LGP	HMF	NYL	GZS
SS	736.69	677.23	570.52	768.5	635.72	366.04	713.80	680.11
TP	288	294	111	275	272	69	202	203
Theanine	40.5	39.5	41.8	24.9	24.1	19.4	39.9	32
AA	67	73	72	50	54	33	66	42
TC	207	194	98	195	180	49	128	138
EGC	37	27	27	10	64	7	9	16
C	5	4	2	3	1	1	1	2
EC	15	15	7	11	15	4	7	8
EGCG	118	117	54	126	84	29	86	83
ECG	32	31	8	46	15	7	25	30
Caffeine	103	114	83	96	120	78	102	93
Reducing sugar	190	145	124	202	117	56	174	184
Polysaccharides	105	104	109	98	105	63	92	114

Relationship between the major taste components and green tea taste

Spearman's correlation analysis showed that there were significantly positive correlations of catechins to astringency taste (r = 0.772); theanine, amino acid together with catechin were significantly correlated with green tea taste (r = 0.738, 0.810 and 0.861, respectively); only theanine had a significant correlation with overall strength taste strangely (r = 0.738); whereas there were no chemical parameters significant correlation with bitterness taste (as shown in Table 7). These data lead us to suppose that green tea taste represented the intensity of taste which came from the average of all tastes in terms of bitterness, astringency and so on.

Table 7. Spearman's correlation coefficients between taste components and common taste notes among eight green teas.

Items	OST	GTT	BIT	AST
SS	0.429	0.238	0.571	0.407
TP	0.310	0.452	0.405	0.515
Theanine	0.738*	0.738*	0.619	0.695
AA	0.690	0.810*	0.595	0.551
TC	0.214	0.333	0.333	0.443
EGC	-0.096	0.180	-0.156	0.223
C	0.417	0.761*	0.454	0.772*
EC	0.061	0.233	0.123	0.333
EGCG	0.452	0.405	0.595	0.371
ECG	0.381	0.429	0.524	0.527
Caffeine	0.190	0.071	0.238	0.156
Reducing sugar	0.405	0.357	0.524	0.527
Polysaccharides	-0.156	0.156	-0.252	0.361

*Correlation is significant at the 0.05 level (two-tailed)

As noted above, green tea taste, bitterness and astringency were assumed as the major taste attributes among various Chinese green teas, the concentration of main taste components in tea infusion provided the important contribution to green tea tastes. It is therefore interesting to develop mathematic models to estimate tea sensory properties by using the tea chemicals as independent variables. Using green tea taste as dependent variables separately, and thirteen tea chemicals as independent variables, the mathematical model, involving theanine, TP and EGC was significant in contributing to the green tea taste level in the cup; Residual statistics showed that the predicated green tea taste value varied from 4.141 to 8.512 with a standard deviation of 1.523. If the predicted samples with higher taste score than this range, this model might not be unhelpful. Apparently, the green tea taste came from the content of theanine, catechin and EGC in end cup, however, when EGC was removed, the equations were not significant; the content of EGC, caffeine and amino acid contributed to bitterness, when theanine was stepped in, the equations were not significant; the content of theanine, ECG, caffeine, catechin the end cup contributed to astringency taste, however, when caffeine was replaced by EGCG, the equation showed was obviously significant (Table 8).

Table 8. Mathematical models for estimation of green tea taste, bitterness and astringency.

Model for	Pearson's linear regressive equation	R^2	Adjusted R^2	SEE
Green tea taste	Taste score = 1.006 + 0.076 theanine + 0.307 catechin - 0.017 EGC	0.916	0.854	0.404
Bitterness	Taste score = -4.446 - 0.098 EGC + 0.063 caffeine + 0.113 amino acid	0.947	0.908	0.640
Astringency	Taste score = 0.322 + 0.127 theanine + 0.125 ECG + 0.338 C – 0.041 EGCG	0.997	0.992	0.131
Overall strength taste	Taste score = 2.384 + 0.129 theanine – 0.051 EGC + 0.007 TP	0.970	0.948	0.111

R^2: R square; SEE: Std error of the estimate

Conclusion

Eight green teas originating from different geographical locations were used in this study. Multi-analysis revealed the linkages between inherent taste constituents and taste attributes. The results from sensory mapping and PCA show the so-called characteristic taste of Chinese green teas that may be described as a complex of fresh green tea, moderate bitterness and subtle astringency.

The contents of TP, TC and AA, caffeine and water extract were similar among those nine Chinese tea leaves, while the concentration of TP, TC in tea infusion of HMF and AJW were lower than other teas, which might due to the limited infusing time. It is considered that the tea infusion should

be prepared under different brewing condition if the same TSS was required. Multivariate analysis suggests that the taste of bitterness and astringency may not be simply explained by existing chemical components, the taste of bitterness is similar to astringency in its interaction during tea taste.

There is considerable variation in sensory attributes among Chinese green teas, in order to decouple the impact of tea cultivars and producing region, different green tea prototypes should be prepared from the same raw material. It is recommended that future studies should be carried out to determine a larger number of samples and discover the molecular basis of taste by multivariate method.

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