*Food Sci. Biotechnol. Vol. 17, No. 2, pp. 349 ~ 356 (2008)*

**Food Science and Biotechnology**



# Sensory Characteristics and Consumer Acceptability of Various Green Teas

**Ok-Hee Lee[1], Hye Seong Lee[1], Young Eun Sung[1], Soh Min Lee[1], Young-Kyung Kim[1,2], and Kwang-Ok Kim[1*]**

[1]*Department of Food Science and Technology, Ewha Womans University, Seoul 120-750, Korea*

[2]*Tea Research, Food Research Institute, Amore Pacific Corporation, Yongin, Gyeonggi 446-729, Korea*

**Abstract** The green tea market is rapidly growing and identifying the driving factors of consumers' liking for the green tea is important in the tea industries. The objectives of this study were to investigate the effects of manufacturing conditions of the green tea on its sensory characteristics, to elucidate its relationship with the consumer liking. A descriptive analysis and consumer acceptability test were conducted for various green tea samples. The samples differed with regard to the source of the tea, the amino acid content, and the processing methods including the roasting temperature. Partial least square regressions (PLS-R) were performed to establish the relationship between the descriptive data and the consumer acceptability data. The PLS-R results showed that the majority of the consumers liked a green tea which has a stronger 'sweet taste' and roasting-related flavors such as 'roasted barley' and 'burnt leaf'. Such sensory characteristics were produced when a sample made of tea leaves mixed with the tea stem was roasted at a high temperature (250°C) in this study.

**Keywords:** green tea, sensory characteristics, descriptive analysis, consumer acceptability, drivers of liking

## Introduction

Tea is one of the most widely consumed drinks around the world. Recently, the awareness of health benefits of green teas has led to the enlargement of the green tea market in Korea (1,2). The expansion of the green tea market encourages the green tea industries to develop new products in order to satisfy the needs of the consumers (3).

Various types of green teas have their own characteristic greenness, clarity, and distinct flavors and such characteristic sensory properties are affected by green tea manufacturing process, green tea sources (e.g., different species and cultivated regions), and various other factors (4,5). Green teas are generally processed with heating such as steaming and roasting to inhibit the enzyme oxidase responsible for the typical fermentation of polyphenols in tea leaves (6). During the roasting process, the levels of furan and pyrazine compounds are increased in the green teas, and these compounds contribute to the unique roasting-related flavors (7,8). Roasting can be performed in many sequential steps at various temperatures; it can also be performed as a single step at a particular temperature. Such variations of the roasting process would result in the different sensory properties of green teas, yet there has been no scientific research studying the effects of the roasting process on the sensory characteristics of green teas.

There are other types of green tea that are processed without roasting or steaming; fermented or semi-fermented teas (e.g., '*ulong*' tea or '*pauchong*' tea). These teas are generally processed with a withering process, during which various flavor compounds are produced (9). Unlike the teas processed with high temperature, these teas are characterized by heavy floral, woody, fruity, and unique refreshing flavors (10) and have been consumed widely in China.

The main source of the green tea is the tea leaves. Other parts of the green tea can also be used in combination with the leaves to make green teas having improved or different sensory characteristics. A source for the desirable additives of the green tea is the green tea plant stem. The tea stem has a higher content of total amino acids than the leaves (11), and thus when it's treated with a high temperature, it can produce increased roasted flavors of the green tea due to more Maillard reaction of those amino acids (7). The objectives of this study were (1) to analyze differences in the sensory characteristics between green teas produced under different processing methods and sources, using descriptive analysis method, (2) to understand Korean consumers' acceptability of these different types of the green teas, and (3) to identify the sensory attributes and underlying processes and source variables that drive Korean consumers' liking for the green tea using partial least square regressions (PLS-R) linked with cluster analysis.

## Materials and Methods

**Materials** Seven different green tea bag samples with various amino acid contents were prepared. The evaluated green tea bag samples included 4 types of green tea leaves: (1) green tea leaves processed at various roasting temperatures (ranging from 170 to 330°C), (2) a green tea leaves/plant stem mix roasted at 250°C, (3) green tea leaves roasted at 170°C, mixed with semi-fermented tea leaves, and (4) semi-fermented tea leaves. The detailed descriptions for each sample were given in Table 1. All the green tea samples were prepared in sliced form in tea bags and provided by Amorepacific Co. (Yongin, Gyeonggi, Korea).

**Sensory descriptive analysis (SDA): Panel selection and training** Eight female panelists (22-44 years old) from the Department of Food Science and Technology at Ewha

*Corresponding author: Tel: +82-2-3277-3095; Fax: +82-2-3277-3095
E-mail: kokim@ewha.ac.kr
Received August 4, 2007; accepted September 27, 2007

**Table 1. The descriptions for the green teas samples used in the experiment**

| Green tea identification | Type of tea | Amino acid content[1] (%) | Roasting temperature[2] (°C) |
|---|---|---|---|
| GT1 | Tea leaves (100%) | 1.55 | 170 |
| GT2 | Tea leaves (100%) | 3.00 | 180 |
| GT3 | Tea leaves (100%) | 1.20 | 200 |
| GT4 | Tea leaves (100%) | 0.50 | 330 |
| GS | Tea leaves (70%) + stem[3] (30%) | 1.70 | 250 |
| GS-F | Tea leaves (70%) + semi-fermented tea leaves (30%) | 2.25 | 170 |
| S-F | Semi-fermented tea leaves (100%) | 2.25 | -[4] |

[1]Estimated before processing.
[2]Roasting time was 15 min.
[3]Stems of green tea tree.
[4]No roasting.

Womans University (Seoul, Korea) participated in the sensory descriptive analysis of the green teas. Among them, 4 panelists were experienced in the descriptive analysis of green teas. The other 4 were selected using a screening procedure which is based on their discrimination ability. The discrimination tests for the screening consisted of 10 sets of triangle tests discriminating between different types of green teas and the 4 basic tastants. Each candidate performed 2 replications of the 10 triangle tests and 10 people (23-44 years old) who correctly answered more than 70% of the tests were first selected as potential panelists. Only 4 out of 10 showed consistent performances during the initial training and so remained in the descriptive panel together with the 4 experienced panelists for the further training.

The panelists were exposed to various types of green teas and generated sensory descriptors for each sensory attribute, and defined them in consensus. And then they selected physical reference samples for the sensory descriptors for further concept alignment on the selected sensory attributes. They also developed the most objective and efficient evaluation procedure in consensus and the training continued until they achieved consistency in the sample evaluation using the developed procedure. The training sessions were held on 4 days per week over 8 weeks and each training session took about 1 hr.

**SDA: Sample preparation and presentation** The samples were prepared for the analytical descriptive analysis according to the following procedure: 1 L of filtered (Ceramic Filter System, Fariey Industrial Ceramics Ltd., London, UK) and heated tap water (80°C) was poured into a 1-L beaker. The beaker was put into a shaking water bath (C-SKW-1; Chang-Shin Scientific Co., Seoul, Korea) which was set at 80°C, 40 rpm for 1 min. Eight green tea bags (1.5 g of green tea per bag) were put into beakers and the beakers were covered with airtight lids (Sunrise Balanced Lid; IFFCO, Seoul, Korea). Each green tea bag was infused for 1 min and removed from the beaker. The infusing methods were determined in a preliminary experiment, taking into account the manufacturer's suggestion. The green tea was cooled by putting the beaker into cold water (15±2°C) until the temperature of the sample reached at 60±2°C (approximately for 2.5 min). The infused green tea was poured into a 1-L thermos flask (AHGB-10; Zojirushi, Osaka, Japan) to maintain the temperature until the evaluation started. Just before the evaluation, 120 mL of the green tea was poured into 200 mL thermos flasks (IB-020TPY; Sejongisoli, Daegu, Korea) that had been pre-warmed with boiled water, and given to the individual panelists along with 50-mL tasting beakers. At the time of the evaluation, the temperature of the samples was 50±2 °C. The samples were coded with 3-digit random numbers, and the presentation order of all 7 samples was randomized. Filtered water (the same as that used for the preparation of the green tea; 45±2°C) was provided to rinse the palate between samples. The separate samples were presented for the evaluation of the appearance as 40 mL aliquots in a 50-mL glass.

**SDA: Intensity evaluation procedure** The quantitative descriptive analysis (QDA®) (12) procedure was used in conjunction with partial adoption of the spectrum descriptive analysis method (13). The intensity of all the selected sensory attributes were evaluated on 15-point category scales, where 1='weak' and 15='strong'. First, the appearance attributes were evaluated under daylight conditions, with the aid of a light box (D65 Superlight-III; Boteck, Siheong, Korea) and the samples were designated with a different random numbers. The flavor evaluation was conducted in the individual booth under dim red light to avoid the bias that may result from differences in color. The panelists were instructed to pour the samples from individual thermos into 50 mL-beakers for tasting. They evaluated the intensity of the attributes after sipping the samples (approximately 10 mL/sip). They rinsed their mouth once with the filtered tap water before tasting each sample. The samples were evaluated 4 times in each session. The evaluation sessions were held twice a day, at 9 and 5 p.m., for 2 consecutive days, and each session took approximately 30 min. Panelists were not permitted to eat or drink anything except for water, or to brush their teeth or gargle, for 1 hr before the session. They were also prohibited from using strong perfumes before the session.

**SDA: Statistical analysis** Multivariate analysis of variance (MANOVA) was performed to evaluate the significance of overall differences among the samples. Since the MANOVA model revealed a significant difference among the samples, analysis of variance (ANOVA), which estimates the effects of variance on each of the attributes, was conducted. The sources of variation were product, panel, replication, and interactions (product × panel, product × replication, and panel × replication). Duncan's multiple range test was performed to separate the means of individual sensory scores between samples. A principal component analysis (PCA) was conducted to summarize and verify the relationships between the mean values for sensory attributes and samples. The PCA method used was covariance matrix extraction with varimax rotation. All of the statistical analyses were conducted using SPSS for Windows software (version 12.0, SPSS, Chicago, IL, USA).

**Consumer acceptability test (CAT): Selection of the consumers** Two-hundred and twenty-four consumers who frequently consume green tea were recruited at local churches and public centers using personal referrals. Consumers were divided into 2 different age groups (20-39 and 40-59 years), and each group consisted of 56 females and 56 males (thus, $n$=112 for each group).

**CAT: Sample preparation and presentation** Samples were prepared as for the descriptive analysis of the green tea. Infused green tea was stored in a 3 L-thermos (TAE-3001; Thermos, Tokyo, Japan) to maintain its temperature. Fifty mL of aliquots of the different green teas were presented in 200-mL paper cups covered with lids. The temperature of the samples at the time of evaluation was 50±2°C. Samples were coded with 3-digit random numbers, and the presentation order of the samples was randomized to minimize the effect of presentation order (14). Filtered tap water (at 20±2°C) was also presented to rinse the mouth.

**CAT: Evaluation procedure** The consumer test was conducted using a one-to-one interview style. For the evaluation of the overall acceptability of the green tea samples, the rank-rating protocol (15), with a 15-point category scale was used. A scale made of a cardboard strip (length 95 cm, height 5.5 cm) labeled as 'dislike very much', 'neither/nor', and 'like very much' at the 1-, 8-, and 15-point positions, respectively was used for the rank-rating protocol and retastings of the previous samples were allowed and the acceptability scores can be changed as needed. Before the test, the consumers were thoroughly explained about the rank-rating protocol and instructed to put the sample in front of the corresponding scores on the strip after deciding upon their degree of acceptability. Consumers rinsed their mouth once before and between samples with the filtered tap water. When consumers wanted more of a particular sample, it was refilled. After evaluating the samples, consumers were requested to answer to a questionnaire regarding their green tea consumption behavior.

**CAT: Statistical analysis** An ANOVA was conducted to evaluate the product effect and Duncan's multiple range test was performed to compare significant differences between sample means for consumer acceptability scores. A PLS-R was performed to establish the relationship between consumer acceptability and the sensory attributes of the green tea samples (16). The consumer acceptability data set (Y variables) was regressed with the descriptive analysis data set (X variables). In this approach, the first latent variable (X-data on the loading plot), a linear combination of all the repressors (X variables) is estimated so that all the regresses (Y variables) are predicted optimally. All X and Y values were projected onto these latent variables. The second latent variables (Y-data on the loading plot) are then estimated as orthogonal to the first latent variables. Thus, theses latent variables model variation in both X and Y values. A full cross-validation method was used for the PLS-R. Consumers were segmented by conducting Wards' hierarchical clustering in order to examine the acceptability of certain samples by particular consumers. PLS-R analysis was again performed on these data to relate the samples' sensory data to the acceptability data from the groups of consumers. The statistical analysis was conducted using SPSS and Unscrambler (version 7.5, 1990, Camo As, Trondheim, Norway).

## Results and Discussion

**Sensory characteristics of the green teas** A total of 15 appearance and flavor attributes were generated to characterize the sensory properties of the green tea from the descriptive analysis. They were 'brownness', 'turbidity', 'sweet taste', 'sour taste', 'bitter taste', 'floral', 'cut grass', 'roasted barley', 'chestnut shell', 'dried straw', 'burnt leaf', 'musty', 'refreshingness', 'astringency', and 'metallic'. The descriptions for the attributes with the reference samples were given in Table 2. MANOVA conducted on the descriptive analysis data revealed significant differences among the samples ($p$<0.05). Mean values of all the sensory attributes except 'bitter taste' differed significantly between the samples (ANOVA, $p$<0.05) (Table 3).

For the appearance attributes, 'brownness' and 'turbidity', the samples GT4 and GS exhibited significantly higher intensities than other samples. Such strong 'brownness' of the GT4 and GS could be due to their higher roasting temperature. Kumazawa *et al.* (17) reported that during the roasting process of green tea, chlorophyll compounds, which contributed to the green color, were converted to pheophytin, pheophobid, and porphyrins, which contributed to the brown color. For the taste attributes, the GT4 and GS showed the highest intensity for 'sweet taste,' while the S-F showed the lowest intensity. Kim *et al.* (18) reported that the sweet taste of the green tea could be attributable to the amino acid content. However, in this study, the GT4 and GS, which had lower amino acid contents (before roasting) than the GT2, GS-F, and S-F, exhibited the highest intensity of the sweet taste. It appears that there might be other sensory properties such as conceptually sweet odor, 'roasted barley' that was the highest in the GT4 and GS had an effect on the evaluation of the 'sweet taste' intensity. For 'sour taste', the S-F rated the highest, while the GT2 rated the lowest intensity although the differences among the samples were minor. Sanderson and Graham (19) reported that the 'sour taste' of black teas was related to the contents of organic acids such as citric, malic, and succinic acids. The contents of the organic acid in black teas tend to increase during the fermentation period (19). As in black tea, the samples of green teas which comprised semi-fermented leaves seem to exhibit a more intense 'sour taste'.

For flavor attributes, the samples S-F and GS-F, which contained semi-fermented teas, rated higher for 'floral', 'musty', and 'refreshingness' than other non-fermented

**Table 2. Definitions and reference samples used for the selected sensory attributes of green teas**

| Sensory attributes | Definitions | References samples |
|---|---|---|
| Brownness | Intensity of brown color of green tea | |
| Turbidity | Turbidity of green tea | |
| Sweet taste | Fundamental taste sensation of which sucrose is typical | 0.1% Sucrose (Ducksan Pure Chemical Co., Ltd., Ansan, Gyeonggi, Korea) solution |
| Sour taste | Fundamental taste sensation of which sodium chloride is typical | 0.035% Citric acid (Ducksan Pure Chemical Co., Ltd.) solution |
| Bitter taste | Fundamental taste sensation of which caffeine and quinine is typical | 0.05% Caffeine (Sigma-Aldrich Chemical Co., Ltd., St. Louis, MO, USA) solution |
| Floral | Aromatics associated with flower such as jasmine | 10 g Jasmine tea (1 tea bag, Chian Jasmine, Amorepacific Corp., infused with 200 mL boiling water for 2 min) mixed with 60 g green tea (1 green tea bag, Daunlyeng, Dong Suh Foods Co., Ltd., infused with 200 mL boiled water for 1 min) |
| Cut grass | Aromatics associated with cut grass | 10 g Sedum sarmentosum |
| Roasted barley | Aromatics associated with roasted barley | 25 g Roasted-barley tea (2 g roasted barley, Roasted-barley tea, Dong Suh Food Co., Ltd., infused with 200 mL boiling water for 2 min) mixed with 45 g green tea (1 green tea bag, Daunlyung, Dong Suh Foods Co., Ltd., infused with 200 mL boiled water for 1 min) |
| Chestnut shell | Aromatics associated with chestnut shell | 30 g Chestnut shell (local supermarket, Seoul, Korea) boiled with 500 mL water at low heat for 10 min |
| Dried straw | Aromatics associated with dried straw | 10 g Dried straw |
| Burnt leaf | Aromatics associated with burnt leaf | 1 g Burnt leaves |
| Musty | Aromatic characteristics of old books or decaying wood | Old book |
| Refreshingness | Refreshing feeling associated with semi-fermented green tea | Semi-fermented green tea (Pojong tea, Tea Home Co., Ltd., Taipei, Taiwan) |
| Astringency | The feeling which shrivels the tongue associated with tannins | 0.1% Tannic acid (Ducksan Pure Chemical Co., Ltd.) solution |
| Metallic | Aromatics associated with metals, tin, and iron | Stainless steel spoon |

**Table 3. The mean intensity scores for the sensory attributes[1)] of green teas[2)]**

| Sensory attributes | GT1 | GT2 | GT3 | GT4 | GS | GS-F | S-F |
|---|---|---|---|---|---|---|---|
| Brownness | $4.34^{c}$ | $4.59^{c}$ | $3.47^{d}$ | $6.88^{a}$ | $6.91^{a}$ | $5.31^{b}$ | $5.00^{bc}$ |
| Turbidity | $3.34^{b}$ | $3.53^{b}$ | $3.06^{b}$ | $4.72^{a}$ | $4.44^{a}$ | $3.44^{b}$ | $3.66^{b}$ |
| Sweet taste | $3.94^{bc}$ | $4.59^{b}$ | $4.25^{b}$ | $7.19^{a}$ | $7.09^{a}$ | $4.47^{b}$ | $3.44^{c}$ |
| Sour taste | $3.69^{ab}$ | $3.00^{c}$ | $3.28^{bc}$ | $3.16^{bc}$ | $3.31^{bc}$ | $3.72^{ab}$ | $4.06^{a}$ |
| Bitter taste | $4.78^{a}$ | $4.13^{a}$ | $4.28^{a}$ | $4.22^{a}$ | $4.66^{a}$ | $4.84^{a}$ | $4.88^{a}$ |
| Floral | $4.53^{c}$ | $3.84^{cd}$ | $3.63^{d}$ | $2.34^{e}$ | $2.47^{e}$ | $5.56^{b}$ | $7.63^{a}$ |
| Cut grass | $6.69^{a}$ | $5.06^{b}$ | $4.84^{b}$ | $2.34^{c}$ | $2.53^{c}$ | $4.44^{b}$ | $4.97^{b}$ |
| Roasted barley | $3.16^{bc}$ | $3.50^{bc}$ | $3.63^{b}$ | $6.81^{a}$ | $6.97^{a}$ | $3.56^{bc}$ | $2.84^{c}$ |
| Chestnut shell | $4.81^{bc}$ | $5.63^{a}$ | $5.19^{ab}$ | $4.12^{c}$ | $4.16^{c}$ | $4.78^{bc}$ | $3.41^{d}$ |
| Dried straw | $4.31^{a}$ | $4.16^{a}$ | $4.25^{a}$ | $4.34^{a}$ | $4.16^{a}$ | $3.84^{ab}$ | $3.41^{b}$ |
| Burnt leaf | $3.13^{bc}$ | $3.44^{b}$ | $3.38^{b}$ | $7.03^{a}$ | $7.37^{a}$ | $3.16^{bc}$ | $2.69^{c}$ |
| Musty | $3.34^{c}$ | $2.84^{cd}$ | $3.22^{c}$ | $2.53^{d}$ | $2.41^{d}$ | $4.69^{b}$ | $5.50^{a}$ |
| Refreshingness | $3.00^{c}$ | $2.50^{d}$ | $2.69^{cd}$ | $1.84^{e}$ | $1.87^{e}$ | $4.19^{b}$ | $5.13^{a}$ |
| Astringency | $4.56^{a}$ | $4.28^{ab}$ | $4.25^{ab}$ | $3.72^{b}$ | $4.09^{ab}$ | $4.50^{ab}$ | $4.06^{ab}$ |
| Metallic | $3.03^{a}$ | $2.72^{ab}$ | $3.13^{a}$ | $2.66^{ab}$ | $2.44^{b}$ | $2.72^{a}$ | $3.16^{a}$ |

[1)]Means within a row not sharing a superscript letter are significantly different ($p<0.05$, Duncan's multiple range test); Y=product+panel+replication+product*panel+product*replication+panel*replication.
[2)]See Table 1 for abbreviation.

teas. In agreement with these results, it has been reported that semi-fermented teas such as '*pauchong*' tea are characterized by a unique floral flavor like jasmine and rose, which is caused by the withering process involved in the fermentation process (20). Choi (20) reported that semi-fermented teas have flavor compounds such as 1-penten-3-ol, 3-methyl butanol, and (Z)-2-penten-1-ol and these compounds are associated with musty odors in fermented foods (21). Moon *et al.* (10) reported that the floral, fruity, and unique refreshing flavors which cannot be found in original green teas are produced by semi-fermented teas as a result of the withering process. On the other hand, Togari *et al.* (22) studied that relationship between sensory properties and chemical components using 44 tea samples including '*ulong*' tea, '*pauchong*' tea, green tea and reported that the 'fresh floral' aroma was related negatively to the methyl pyrazine content, which is generated during the heating process. Confirming their results, the samples GT4 and GS which were roasted at the highest temperatures in this study, showed the lowest intensity for the 'floral' flavor. The intensity of the 'cut grass' flavor was the highest for the GT1, which was roasted at a lower temperature than other samples, while it was the lowest for GT4 and GS, roasted at higher temperatures. This supports the results of Sanderson and

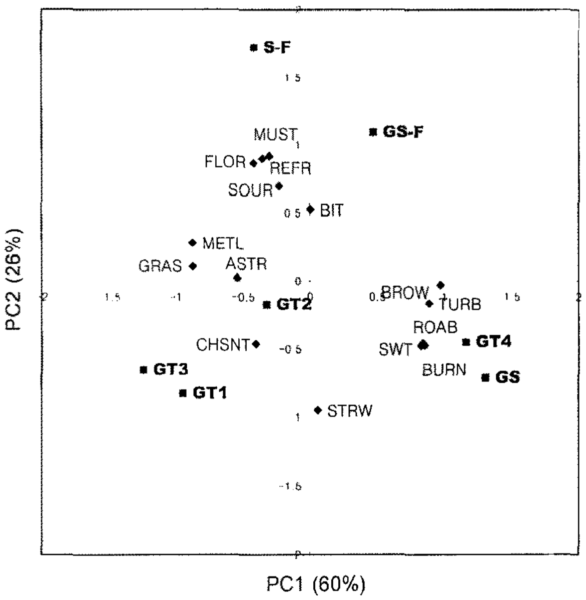


**Fig 1. Principal component (PC) loadings and scores of the sensory attributes[1)] of green tea for component 1 and 2.** (See Table 1 for sample abbreviations.) [1)]BROW, brownness; TURB, turbidity; SWT, sweet taste; SOUR, sour taste; BIT, bitter taste; ASTG, astringency; FLOR, floral; GRAS, cut grass; ROAB, roasted barley; CHSNT, chestnut shell; STRW, dried straw; BURN, burnt leaf; MUST, musty; REFR, refreshingness; METL, metallic.

Graham (19) that the grassy odor of the teas is reduced by the roasting process.

The GT4 and GS showed the most intense 'roasted barley' and 'burnt leaf' and the least intense 'musty' and 'refreshingness'. The strong 'roasted barley' and 'burnt leaf' attributes of these samples could be due to pyrazines, pyrroles, and furanic compounds generated by the high roasting temperature used in their production (7,20). Shin (23) reported that catechin compounds are responsible for the chestnut-shell-like flavor of green teas. In the present study, the 'chestnut shell' flavor was the least intense in the S-F. For the 'dried straw', 'astringency', and 'metallic' attributes, the differences among the samples were only minor.

The PCA results indicated that PC1 and PC2 explained 60 and 26% of the total variance, respectively (Fig. 1). The green tea samples were separated along the PC1 according to the intensity of their 'brownness', 'turbidity', 'sweet taste', 'roasted barley', 'burnt leaf', 'cut grass', 'astringency', and 'metallic' which were mostly affected by the roasting temperature of the samples. The position of the green tea samples on the PC2 was determined by 'sour taste', 'bitter taste', 'floral', 'musty', 'refreshing', 'chestnut shell' and 'dried straw', which were mostly affected by the addition of semi-fermented teas. Thus, the GT4 and GS which are loaded highly on the positive PC1 dimension and negatively on the PC2 were shown to be similar each other. The GT1, GT2, and GT3 which are comprised only green tea leaves (100%) roasted at a lower temperature, were loaded negatively on both PC1 and PC2, yet the GT1 and GT3 were shown to be more similar each other. The GS-F (30% semi-fermented tea) and S-F (100% semi-fermented tea) which were positively loaded on the PC2 dimension,

**Table 4. The mean scores[1)] obtained from the consumer acceptability test for green teas[2)]**

| Samples | GT1 | GT2 | GT3 | GT4 | GS | GS-F | S-F |
|---|---|---|---|---|---|---|---|
| | $8.71^{abc}$ | $8.47^{bc}$ | $8.57^{bc}$ | $8.93^{ab}$ | $9.33^{a}$ | $8.20^{c}$ | $7.39^{d}$ |

[1)]Means within a row not sharing a superscript letter are significantly different ($p$<0.05, Duncan's multiple range test).
[2)]See Table 1 for abbreviation.

were relatively more similar each other having higher intensity of 'musty', 'floral', 'refreshingness' and 'sour' as described earlier.

Examining the correlation coefficients among the attributes confirmed that there were positively highly significant correlations ($p$<0.01) between 'sweet taste' and 'roasted barley' ($r$ = 0.99), 'sweet taste' and 'burnt leaf' ($r$ = 0.99), 'roasted barley' and 'burnt leaf' ($r$ = 1.00), 'musty' and 'floral' ($r$ = 0.97), 'musty' and 'refreshingness' ($r$ = 1.00), 'floral' and 'refreshingness' ($r$ = 0.99). Also, 'sweet taste' showed negatively significant correlations ($p$<0.05) with 'floral' ($r$ = –0.85), 'cut grass' ($r$ = –0.89), 'metallic' ($r$ = –0.83), and 'refreshingness' ($r$ = 0.76). These results support that for Korean consumers there might be conceptual congruency among 'sweet taste', 'roasted barley', and 'burnt leaf' attributes, enhancing each others' intensities. Such interactive enhancement could also occur among attributes, 'musty', 'floral', and 'refreshingness', while it is possible for stronger 'floral' and 'refreshingness' attributes depress the 'sweet taste' intensity.

**Consumer acceptability of green teas** There was no significant differences between the different age groups and different gender groups for the acceptability of green tea samples. The mean acceptability scores of green tea samples obtained from the total consumers tested are given in Table 4. The GS showed the highest acceptability by the tested consumers but it did not significantly different from the samples GT4 and GT1. The S-F made of 100% semi-fermented tea leaves showed the least acceptability and the GS-F made of 70% tea leaves with 30% semi-fermented tea leaves showed the second least acceptability. The GS and GT4 were roasted at a higher temperature compared to the other samples and characterized by strong 'sweet taste', 'roasted barley', and 'burnt leaf' attributes (Table 3, Fig. 1). Therefore, it appears that these sensory attributes are the drivers of liking for green tea for Korean consumers although this was not true for the sample of GT1. The S-F and GS-F were less acceptable and had a strong 'sour taste', 'refreshing', 'floral', and 'musty' flavor indicating these sensory attributes are drivers of disliking for green tea for Korean consumers. It was thought that there is a possibility that these samples had lower acceptability scores because Korean consumers were not familiar with the sensory properties of these types of green teas since such semi-fermented teas were not broadly introduced in Korea yet.

**Relationship between consumer acceptability and sensory attributes of green teas** The PLS-R results indicated that PC1 and PC2 explained 61 and 26% of the X-data set (descriptive analysis data), respectively, and 24 and 18% of the Y-data set (consumer acceptability data) from total variance, respectively. In the loading plot, each dot represents the acceptability of the tea samples for each consumer, revealing the direction and intensity of consumer likings for sensory attributes of green tea (Fig. 2A). From this plot, the liking for each green tea sample can also be compared (Fig. 2B). Few consumers liked S-F and GS-F samples and more than half of the consumers were located on the negative side of the PC1 axis toward where is opposite from those samples (Fig. 2B). From the direction of the consumers on PC1, it is shown that consumers liked the GT4 and GS the most, although they are well distributed along the positive side of PC2. Again, the GT4 and GS exhibited a high intensity for 'sweet taste', 'burnt leaf', and 'roasted barley' and low intensity for 'sour taste' and 'floral'. The GT2 and GT3, which were most highly located on PC2, exhibited a low intensity for 'sour taste' and 'floral' as well. Thus, it could be seen that most of the consumers liked the attributes of 'sweet taste', 'burnt leaf', and 'roasted barley' of the green teas and disliked the attributes of 'sour taste' and 'floral'. Consistent with this result, Shin (23) and Park *et al.* (24) reported that Koreans prefer roasted green tea to stemmed green tea because of the unique roasting-related flavors of the former. Therefore, 'sour taste' and 'floral' flavor seemed to be drivers of disliking for green tea, while roasting-related flavors seemed to be drivers of liking for Korean consumers, and this might be associated with the habit of Koreans' drinking tea made from slightly roasted rice (24). Similarly in Japan, green tea processed at a very high roasting temperature (180°C), which is called '*hoji-cha*', is very popular (20). *Hoji-cha* is, in fact, made of low quality green tea, that is harvested during the late harvest season and thus has low amino acid contents. Yet the high temperature roasting process decreases its astringency and produces the roasted flavors of green tea (20). Thus, although the *hoji-cha* does not have much of the original green tea flavor, it has become very popular because of its high economical efficiency and strong roasted flavors.

**Grouping of consumers according to similar acceptability scores** The performance of cluster analysis on consumer data resulted in 3 groups of the consumers according to their acceptability for the green teas. The results of ANOVA on the clusters, their demographic information, and their mean acceptability rating scores for each sample are given in Table 5-7, respectively. As seen in Table 5, consumers tested used the scale for their acceptability in the similar manner leading to no significant effect. Yet, it showed the significant interaction between the cluster and sample ($p<0.001$), indicating that the each consumer cluster tended to like different green tea samples.

The results of PLS-R indicated that PC1 and PC2 explained 58 and 29%, respectively, of the X-data set (descriptive analysis data) and 43 and 19% of the Y-data set (segmented consumer acceptability data) from the total variance, respectively (Fig. 3). Cluster 1 (62.9%), which comprised the majority of the consumers, was characterized by those who liked the GS the most and the S-F the least (Table 7). The GS, which contained 30% tea plant stem and was processed at a high roasting temperature, was characterized by strong roasting-related flavors such as 'roasted barley' and 'burnt leaf'. Therefore, after mixing the stem which has the higher content of amino acids, to the green tea leaves which does not have very high content of amino acids, roasting them at a high temperature (>200

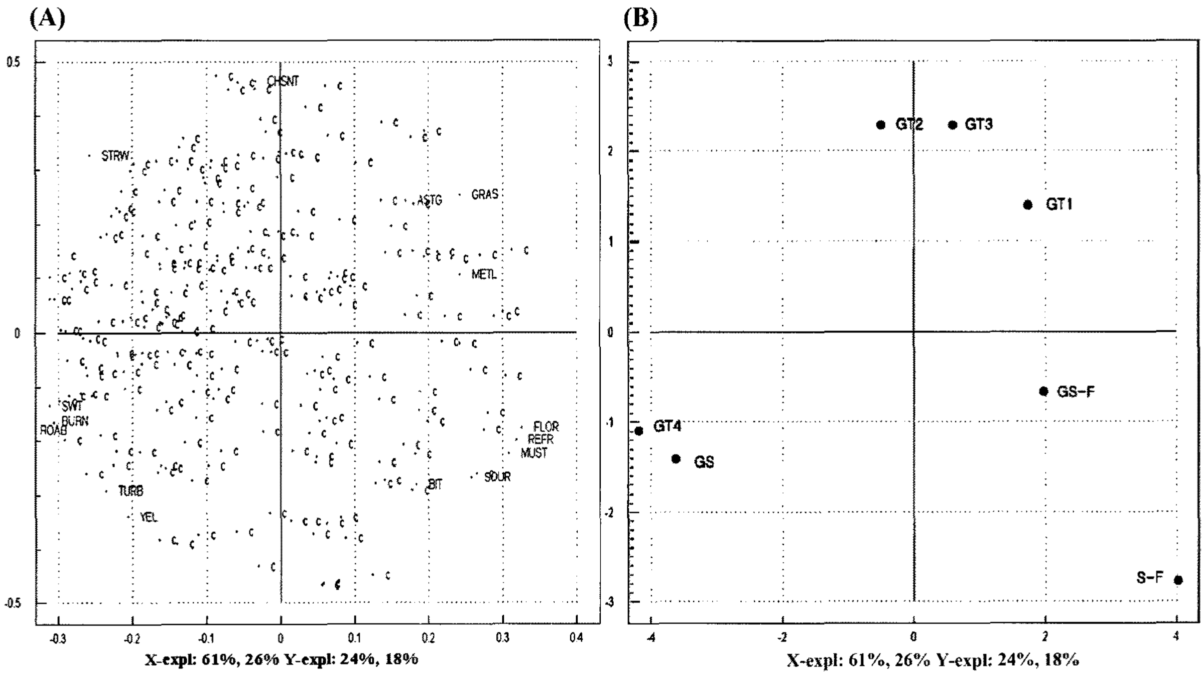


**Fig 2. PLS-R results for (A) X- and Y-loading and (B) sample map indicating relationship between sensory attributes[1)] and consumer acceptability.** (See Table 1 for sample abbreviations.) [1)]BROW, brownness; TURB, turbidity; SWT, sweet taste; SOUR, sour taste; BIT, bitter taste; ASTG, astringency; FLOR, floral; GRAS, cut grass; ROAB, roasted barley; CHSNT, chestnut shell; STRW, dried straw; BURN, burnt leaf; MUST, musty; REFR, refreshingness; METL, metallic.

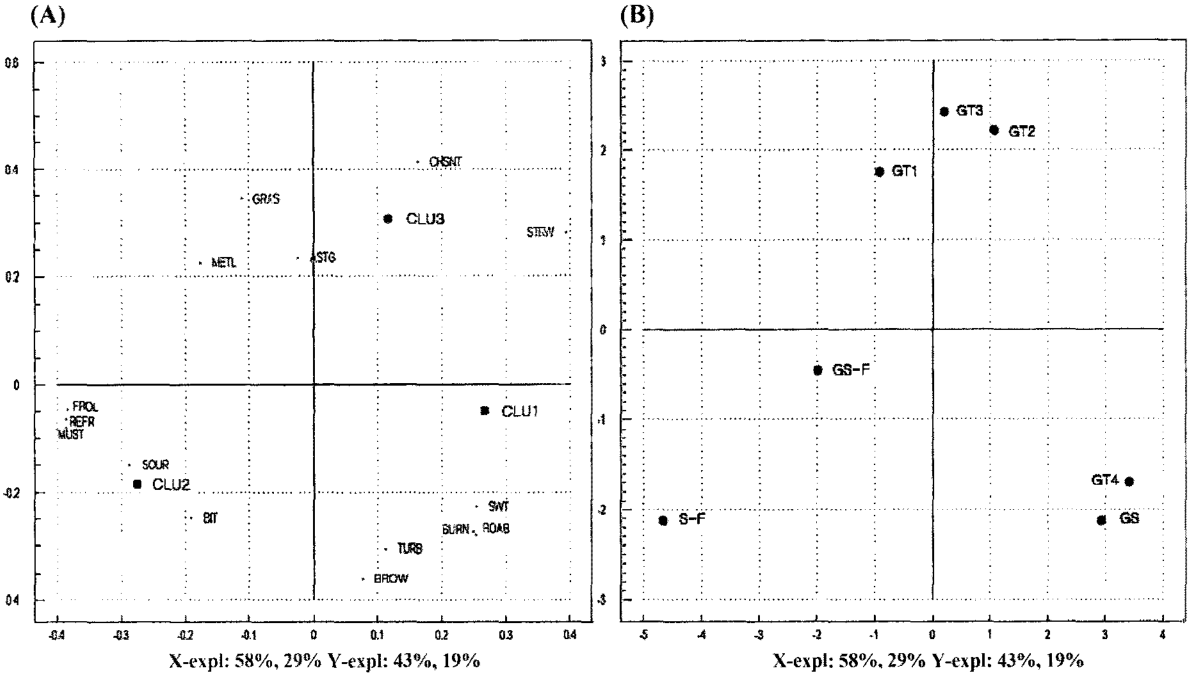


**Fig. 3. PLS-R results for (A) X- and Y- loading and (B) sample map indicating relationship between sensory attributes and cluster hedonic rating.** (See Table 1 for sample abbreviations.) [1)]BROW, brownness; TURB, turbidity; SWT, sweet taste; SOUR, sour taste; BIT, bitter taste; ASTG, astringency; FLOR, floral; GRAS, cut grass; ROAB, roasted barley; CHSNT, chestnut shell; STRW, dried straw; BURN, burnt leaf; MUST, musty; REFR, refreshingness; METL, metallic.

**Table 5. F-values from the ANOVA procedure applied to the consumer rating of clusters**[1)]

| Source of variation | d.f. | F-value |
|---|---|---|
| Product | 6 | 3.085** |
| Cluster | 2 | 0.128 |
| Product*cluster | 12 | 24.021*** |

[1)]Y = product + cluster + product*cluster; ** $p<0.01$; *** $p<0.001$.

**Table 6. Demographic profile of 3 clusters for green teas**

| | Cluster 1 (%) | Cluster 2 (%) | Cluster 3 (%) |
|---|---|---|---|
| Consumers | 62.9 | 18.3 | 18.8 |
| Gender | | | |
| Male | 53.2 | 53.7 | 35.7 |
| Female | 46.8 | 46.3 | 64.3 |
| Age | | | |
| 20-39 | 46.8 | 56.1 | 54.8 |
| 40-59 | 53.2 | 43.9 | 45.2 |

°C) seem to produce much liked roasting-related flavors by the majority of the Korean consumers regardless their gender and age.

Consumers in cluster 2 liked the S-F the most, which was prepared from 100% semi-fermented tea leaves (Table 7), although they were only 18.3%. This sample had strong fermented attributes such as 'sour taste', 'musty', 'refreshing', and 'floral'. Cluster 3 (18.8%) was characterized by consumers who liked the GT2, GT4, and GT1 the most and the GS and S-F the least (Table 7). However, the consumers in cluster 3 did not show any consistency in their mean liking for related sensory attributes; thus this grouping may

**Table 7. Mean acceptability values for 3 clusters obtained from hierarchical cluster analysis**[1)]

| Cluster | No. | GT1 | GT2 | GT3 | GT4 | GS | GS-F | S-F |
|---|---|---|---|---|---|---|---|---|
| 1 | 141 | $8.87^{b}$ | $7.73^{c}$ | $8.86^{b}$ | $8.82^{b}$ | $11.06^{a}$ | $7.54^{c}$ | $6.64^{d}$ |
| 2 | 41 | $7.22^{d}$ | $8.71^{c}$ | $7.07^{d}$ | $7.71^{c}$ | $7.17^{d}$ | $9.95^{b}$ | $11.51^{a}$ |
| 3 | 42 | $9.67^{ab}$ | $10.71^{a}$ | $9.07^{b}$ | $10.48^{a}$ | $5.64^{c}$ | $8.71^{b}$ | $5.90^{c}$ |

[1)]Mean values a row not sharing a superscript letter are significantly different ($p<0.05$, Duncan's multiple range test).

be due to experimental errors. From the examination of both Table 3 and 7, it was thought that the description on the PLS-R plot for cluster 3 in Fig. 3 would be also meaningless.

## Acknowledgments

This work was supported by Amorepacific Co. and the Brain Korea 21 project in 2006.

## References


1. Khokhar S, Magnusdottir SGM. Total phenol, catechin, and caffeine contents of teas commonly consumed in the United Kingdom. J. Agr. Food Chem. 50: 565-570 (2002)
2. Choi JH, Nam JO, Kim JY, Kim JM, Paik HD, Kim CH. Antioxidant, antimicrobial, and antitumor activities of partially purified substance(s) from green tea seed. Food Sci. Biotechnol. 15: 672-676 (2006)
3. Lee KCL. A study on the life style of green tea consumers. J. Korean Tea Soc. 10: 7-24 (2004)
4. Hara Y, Luo S, Wickremasinghe RL, Yamanishi T. Special issue on tea. Food Rev. Int. 11: 371-545 (1995)
5. Lee JY, Wang LF, Baik JH, Park SK. Changes in volatile compounds of green tea during growing season at different culture

areas. Korean J. Food Sci. Technol. 39: 246-254 (2007)
6. Gong SY. Processing and multiple application of the in China. J. Korean Tea Soc. 79-95 (2000)
7. Ko YS, Lee IS. A study on the changes of the components on the steaming and roasting green tea after heat treatments according to time. J. Home Eco. Assoc. 23: 29-36 (1985)
8. Kawakami M, Yamanishi T. Formation of aroma components in roasted or pan-fired green tea by roasting or pan-firing treatmemt. Nippon Nogeik. Kaishi 73: 893-906 (1999)
9. Chen CN, Liang CM, Lai JR, Tsai YJ, Tsay JS, Lin JK. Capillary electrophoretic determination of theanine, caffeine, and catechins in fresh tea leaves and *'ulong'* tea and their effects on rat neurosphere adhesion and migration. J. Agr. Food Chem. 51: 7495-7503 (2003)
10. Moon JH, Lee JK, Song BH, Park KH. Aroma of tea. J. Korean Tea Soc. 2: 147-161 (1996)
11. Park JH. Studies on the distribution of the chemical components in different position of tea leaves. J. Korean Tea Soc. 3: 47-56 (1997)
12. Stone H, Sidel JL. Sensory Evaluation Practices. 1st ed. Academic Press, London, UK. pp. 202-220 (1985)
13. Munoz AM, Civile GV. The spectrum descriptive analysis method. pp. 22-34. In: ASTM Manual Series MNL 13, Manual on Descriptive Analysis Testing. Hootman RC (ed). American Society for Testing and Materials, West Conshohocken, PA, USA (1992)
14. Halliday JM, Nicholas B. Designs to balance the effect of order of presentation and first-order carry-over effects in hall tests. J. Sens. Stud. 4: 129-148 (1989)
15. Kim KO, O'Mahony M. A new approach to category scales of intensity: Traditional versus rank-rating. J. Sens. Stud. 13: 241-249 (1998)
16. Chung SJ. Flavor release from ice cream during eating. Food Sci. Biotechnol. 16: 8-17 (2007)
17. Kumazawa K, Kubota K, Masuda H. Influence of manufacturing conditions and crop season on the formation of 4-mercapto-4-methyl-2-pentanone in Japanese green tea (*sen-cha*). J. Agr. Food Chem. 53: 5390-5396 (2005)
18. Kim B-S, Yang W-M, Choi J. Comparison of caffeine, free amino acid, vitamin C, and catechins content of commercial green tea in Bosung, Sunchon, Kwangyang, Hadong. J. Korean Tea Soc. 8: 55-62 (2002)
19. Sanderson GW, Graham HN. On the formation of black tea aroma. J. Agr. Food Chem. 21: 576-585 (1973)
20. Choi SH. Characterization of various tea flavor. J. Korean Tea Soc. 4: 115-133 (1998)
21. Plaehn D, Lundahl DS. An L-PLS preference cluster analysis on French consumer hedonics to fresh tomatoes. Food Qual. Prefer. 17: 243-256 (2006)
22. Togari N, Kobayashi A, Aishima T. Relating sensory properties of tea aroma to gas chromatographic data by chemometric calibration methods. Food Res. Int. 28: 485-493 (1995)
23. Shin MK. The science of green tea. Korean J. Diet. Culture 9: 433-445 (1994)
24. Park JH, Choi HK, Park KH. Chemical components of various green teas on market. J. Korean Tea Soc. 4: 83-92 (1998)