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Research Article

Sensory descriptive evaluation: brewing methods affect flavour of green tea

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Abstract

Commercially available green tea products provide various brewing directions based on type, origin, purpose, etc. Flavour and basic taste of green tea may vary using different brewing styles. The objective of this study was to describe flavour changes of green tea when it is prepared with different water temperatures and brewing times. Green tea samples were brewed at 3 different temperature levels (50, 70, and 95°C) for 1, 2, 5, and 20 min using 3 different green teas from Korea. Highly trained panellists participated in the descriptive sensory analysis using a previously developed green tea lexicon. Canonical Variates Analysis (CVA) was used to compare green tea flavour for each brewing method. CVA, across all 3 green tea samples at 12 different brewing temperature and time combinations, suggested that brown, brown-related attributes (ashy/sooty, burnt/scorched), bitterness and astringent become stronger; and green and green-related attributes (green beans, spinach) become weaker as the brewing time and water temperature increased.

Keywords: Green tea, flavour change, water temperature, brewing time, canonical variates analysis

Introduction

Constituents such as catechins, caffeine, tannin, amino acids and free sugar in green tea contribute to the flavour. Especially, catechins are known to contribute to 70-75% of bitterness and astringency [1, 2]. Caffeine has a bitter taste [3] and tannin has a strong astringent or pungent taste [4]. Amino acids are responsible for brothy taste and free sugars contribute to sweetness [5].

There is some evidence that brewing temperature and length may influence the extraction of the aforementioned constituents. In a study conducted to determine how different brewing conditions change green tea constituents, researchers found that the amounts of tannin, free sugar and total nitrogen in green tea increased as the water temperature and brewing time increased [6]. Research studying the caffeine content of brewed coffee, black tea and green tea found that caffeine content in green tea markedly increased as the water temperature increased [7]. In the same study, researchers used 100°C to compare brewing time and found a minimal effect on caffeine content of the tea. Caffeine has a bitter taste [3] thus, from this study it can be determined that the bitterness of green tea increases as the brewing water temperature increases.

Green tea is considered a functional food with catechins providing the majority of the antioxidants in green tea and the potential health benefits [8, 9]. Thus, green tea products in some countries bear statements such as 'rich in antioxidants' and 'good for your health' on their packages; some products even specify how much antioxidants consumers could potentially receive through consumption of their product. As release of catechins into brewing water can be affected by temperature of brewing water and brewing time, the health benefits of green tea can depend on the brewing methods. Thus, some green tea products recommend using boiling water and 3-5 minutes brew for maximum health benefit, which may result in bitter and astringent green tea.

However, consumers are not willing to trade taste for food functionality [10]. If this applies to green tea, consumers would not enjoy the bitterness and astringency of green tea that could occur when tea is brewed with boiling water for a longer time [6], even though it might be healthier for them. The literature suggests that different brewing methods may result in different flavours for green tea [2, 11]. Therefore, how the flavour of green tea changes at different brewing conditions is important, although there has been limited research on the subject.

Researchers have sought to find optimal brewing conditions using green tea bags [12] and loose green tea leaves [13]. Using tea bags, it was found that soluble solids, phenolics and flavonoids in green tea increased when the temperature of the water and the brewing time increased. Using physicochemical and acceptability data, it was concluded that optimal brewing methods are a combination of 73-83°C water and 5.3-6.3 minutes of brewing time [12].

Using loose green tea leaves, a total of 12 green tea preparation methods (2 water temperature points for 6 brewing lengths) were studied using consumer just-about-right scaling [13]. Researchers recommended optimal brewing at 60°C for 3 minutes or at 80°C for 1 minute based on the just-about-right evaluation from consumers. Interestingly, 70°C, one of the commonly recommended temperatures for brewing green tea leaves was not used

in the research. After the consumer study, tea brewed using the two recommended temperatures was analyzed by a descriptive sensory panel who found that these two brewing methods discriminated among green tea samples. Unfortunately, green tea flavour of only two brewing methods was described. Thus, it appears that flavour of green tea brewed under different conditions needs more thorough research.

The objective of this study was to describe flavour changes of green tea when prepared with different water temperatures and brewing times.

Materials and Methods

Tea samples

Three Korean commercial green tea products were selected as samples because of availability in large quantities of the same harvest date and processing. Two samples were obtained from *Amore Pacific Co.* (Yongin, Korea), a major green tea producing company in Korea. *Sulloc Tea Ouksu (Ouksu)* is a high grade green tea and *Sulloc Tea Soon (Soon)* is a medium grade green tea. Green teas made with tea leaves harvested earlier in the season generally have higher amino acid contents and are considered as higher grade. The third sample, *Myungsul Sejac (Sejac)* was obtained from *Myungsulwon* (Suncheon, Korea) and is a high grade green tea. All three samples were in leaf form because that form is commonly used for green tea brewing in Asian countries and is more appropriate to test the effects of brewing length. The green teas in tea bags is processed and chopped finely to release flavour and nutrients in a shorter time and may not be appropriate for testing different lengths of brewing time. The three green tea samples, with a normal shelf life of 2 years, were stored at 4°C before being tested and evaluated within three months of packaging.

Tea Preparation

Packaged green tea samples were taken from the refrigerator and allowed to reach room temperature to prevent dew from collecting on the tea leaves when the package was opened. The tea samples were prepared using a small white porcelain tea pot (approximately 350mL in volume), a porcelain strainer, and a porcelain bowl, which is widely used in Asian countries to brew teas [2, 11]. In addition, using porcelain equipment would not impart any additional flavours to the tea. Reverse osmosis, deionized, carbon filtered water was heated to brewing water temperatures and used for warming the pot prior to brewing the tea. Warming is a typical procedure when brewing tea and was done to prevent the acute temperature of brewing water from dropping. After warming the pot, the water was poured into the bowl to warm the bowl; Ten grams of tea was used with 3 different water temperatures and 4 different lengths of brewing times in combinations resulting in12 different combinations.

Three different water temperatures represented hot tap water at 50˚C; 70˚C the most commonly recommended temperature for brewing; and “boiling water” at 95˚C. Brewing times were 1, 2, 5, and 20 minute(s) long. One, 2, and 5 minute(s) were most commonly recommended from various package directions. In addition, 20 minutes were added to examine an extreme length of brewing time. All three of the green tea samples were prepared using 12 different brewing combinations and each tea was evaluated in triplicate. The tea was placed in the teapot, followed by 300 mL of the desired temperature of water and then brewed for the appropriate length of time. While the tea was brewing, the pot was swirled clockwise 10 times within the first minute to simulate the typical brewing of tea.

After the first minute, the teapot was left undisturbed until the brewing time ceased. The brewed tea was then poured through a strainer into the warmed bowl. Approximately 45 mL of brewed green tea was poured into each pre-warmed white porcelain tea cup.

Panellists

Six highly trained panellists from the Sensory Analysis Center at Kansas State University served as the panel in this study. The panellists had completed 120 hours of general training and had a minimum of 1,000 hours of general sensory evaluation experience including a variety of beverages including green tea and vegetables. This was similar to the panel that developed a standardized green tea lexicon [14].

Serving Procedure and Sample Evaluation

Green tea samples were coded with three-digit random codes and served one at a time. The same sample was prepared a second time, 5 minutes later, to ensure a warm sample for the panellists to evaluate. Each evaluation session lasted 1.5 hours with 15 minutes for each sample evaluation. Panellists used unsalted crackers (Unsalted tops premium saltine crackers, Nabisco, East Hanover, NJ) and reverse osmosis, deionized, carbon-filtered water to cleanse the palate before evaluating the next sample. The panel had three 90-minute sessions for orientation and evaluated all three samples for 12 conditions in 18 90-minutes sessions. The published standardized green tea flavour lexicon [14] was used for the descriptive analysis in this study.

Test Design

The effects of two factors, water temperature (50, 70, and 95°C) and brewing time (1, 2, 5, and 20 minute(s)) were studied for the brewing of green tea. A 3 by 4 factorial design was used. A total of 12 design points were evaluated in triplicate. Design points were evaluated in random order within each replicate.

Data Analyses

The main effects of water temperature and brewing time, and the interaction between water temperature and time were studied using PROC GLM, LSMEANS statement in SAS® (Version 9.1; SAS Institute, Cary, NC, USA). Multivariate Analysis of Variance and Analysis of Variance were conducted using PROC GLM in SAS [15]. Canonical Variates Analysis (CVA) was conducted to show the significance among samples and brewing method combinations using canonical space with confidence regions (SAS® PROC CANDISC). Ninety five percent confidence spheroids were calculated using $\sqrt{(\chi_{\alpha,k}/n)}$, where α=0.05, k=2 (number of dimensions), and n=number of observation [15]. CVA biplots give visual information on data for easier understanding of overall differences or similarities among products. Circles in figures denote 95% confidence spheroids; when 2 circles are overlapping, they are not statistically different at 95% confidence level. The distance between circles shows differences among samples. In other words, if one sample is quite different from another sample, the distance between these 2 circles will be further apart.

Results and Discussion

Of 31green tea flavour attributes in the standardized green tea flavour lexicon [14], only 22 attributes were detected in the three samples in this study: green, asparagus, celery, green beans, green herb, parsley, spinach, brown, ashy/sooty, burnt/scorched, citrus, grain, medicinal, musty/new leather, nutty, seaweed, straw-like, tobacco, bitter, astringent, tooth-etch and sweet aromatic.

All multivariate statistics and F approximations for CVA were significant (e.g. both Wilk's λ and Hotelling-Lawley trace had P-values less than 0.00001) which shows similarity to the univariate analysis where all attributes were significant. The first and second CVs were plotted separately for each green tea product (Figure 1) to simplify the plot. The first canonical variate dimension explained 54.65% of data and the second dimension explained 9.95% of variables. It is evident from CVA biplots that flavour of green tea changes as water temperature and brewing length change.

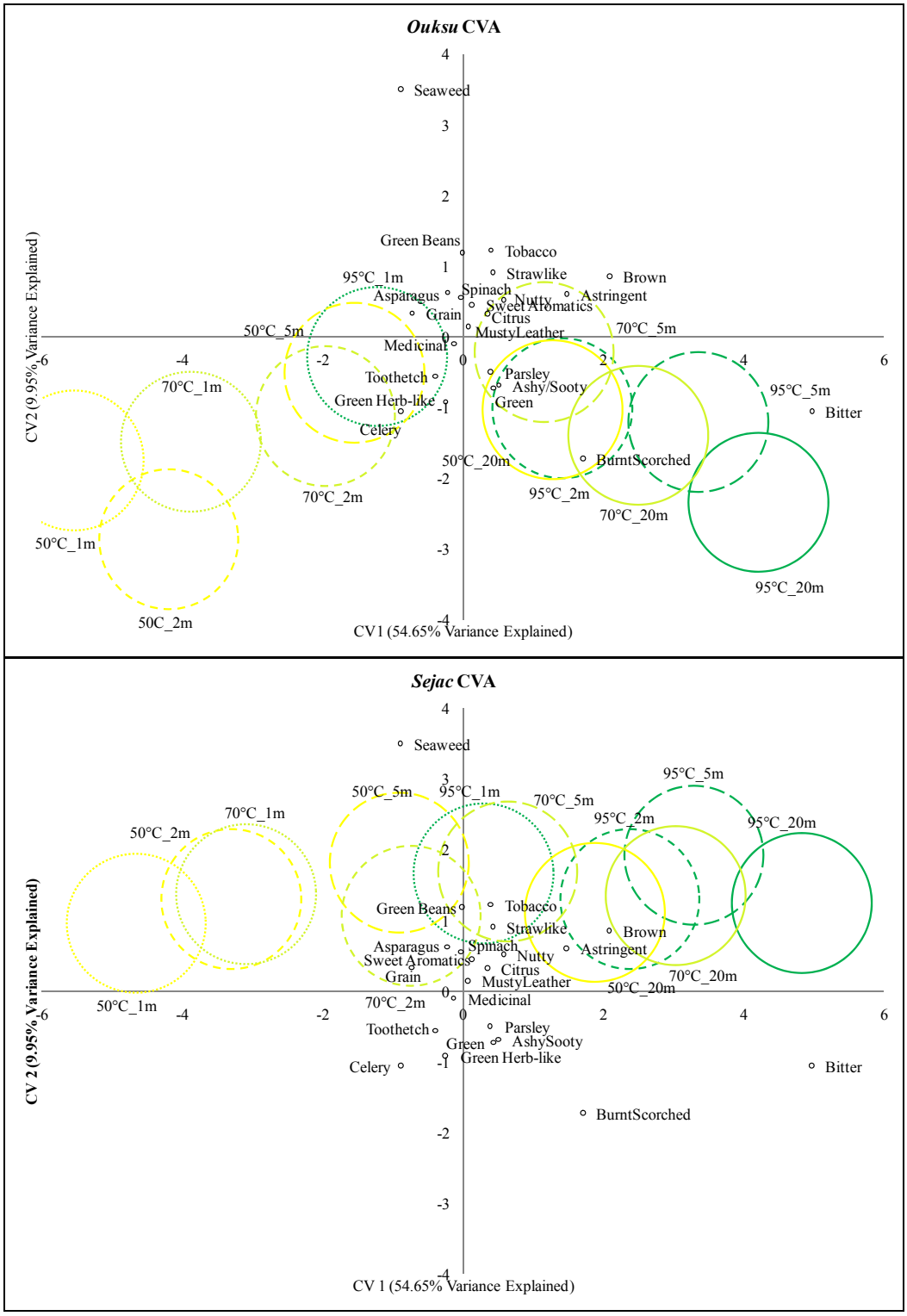
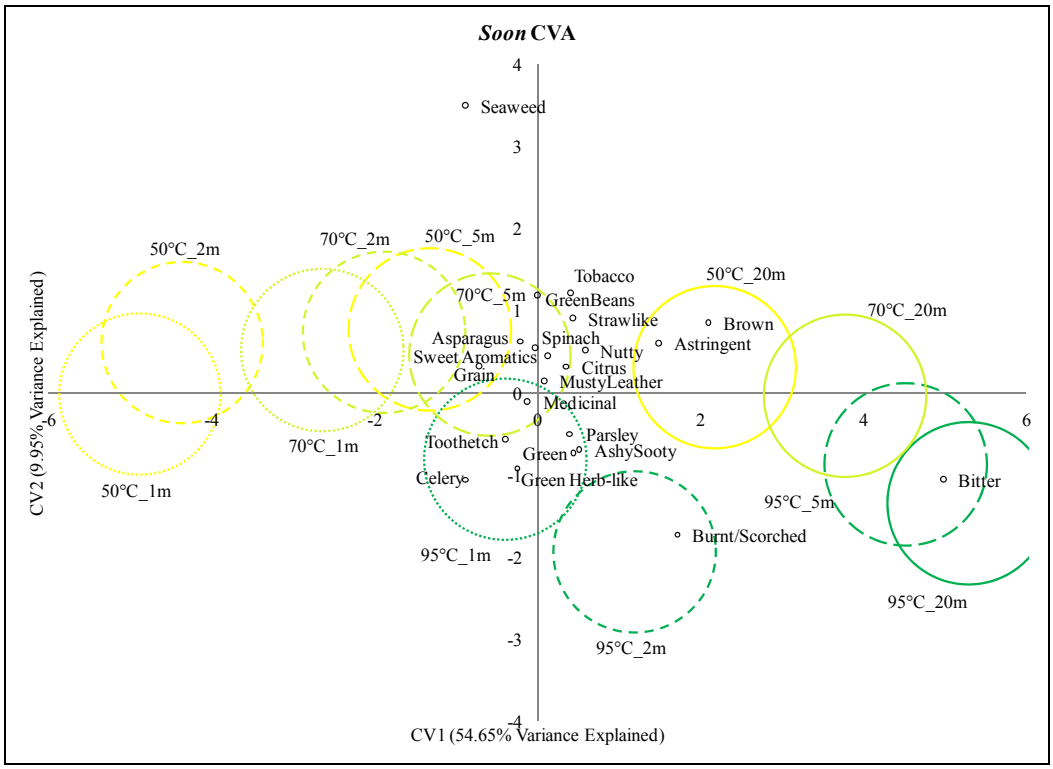


Figure 1(a). Canonical Variates Analyses of *Ouksu*, *Sejac* and *Soon* brewed differently for water temperature[a] and brewing time[b].

Effects of Water Temperature and Brewing Time

Bitter and brown were explained mostly in CV1, probably because intensities of bitterness and brown flavour note differed markedly when different brewing methods were used. The intensities of bitterness and brown note increased as the water temperatures and brewing lengths increased and the differences were almost 6 points of 0 to 15 scale, which is much larger than the change of other attributes (Tables 1, 2 and 3). CV2 explained more flavour terms than CV1 and included terms such as green, asparagus, celery, green beans, green herb-like, spinach, ashy/sooty, seaweed, straw-like, tobacco, seaweed and sweet aromatic attributes. CV1 and CV2 explained almost the same variability for parsley, citrus, medicinal, nutty, tooth-etch and burnt/scorched.



[a] The colours of line reflect the water temperature.

50°C
70°C
95°C

[b] The line styles reflect brewing time.

1 min
2 min
5 min
20 min

Figure 1(b). Canonical Variates Analyses of *Ouksu, Sejac* and *Soon* brewed differently for water temperature[a] and brewing time[b].

Water temperature and brewing time interaction

Twenty attributes had significant interactions with water temperature and brewing time: green, asparagus, celery, green beans, green herb-like, parsley, spinach, brown, ashy/sooty, burnt/scorched, citrus, grain, medicinal, musty/new leather, nutty, tobacco, bitter, astringent, tooth-etch and sweet aromatics. Only seaweed and straw-like did not show significant

interaction between water temperature and brewing time, but main effects for both factors were significant.

However, interactions of asparagus, celery, green herb-like, parsley, ashy/sooty, citrus, grain, medicinal, nutty, tobacco, sweet aromatics may not be meaningful because these attributes were perceived only in some of the samples of each brewing method, not all.

Figure 2 shows some important interactions of water temperature and brewing time: green, spinach, green beans, brown, burnt/scorched, musty/new leather, bitter, astringent, and tooth-etch. As expected, the highest intensity was reached at different temperatures within each length of brew for green-related attributes such as green, spinach, and green beans. The highest intensity was reached more quickly with higher brewing temperature and then decreased. This suggests that flavour compounds responsible for green-related flavours are leached from the leaves fairly quickly and then dissipate. This leaching occurs faster at higher temperatures.

Interestingly, for brown, burnt/scorched, bitter, astringent, and tooth-etch the intensity increased as the water temperature and the length of brew increased. This suggests that more compounds responsible for the flavour notes related to processing in green tea (brown and burnt/scorched) and those potentially related to the functional composition (bitter, astringent, and tooth-etch) continue to be leached from the leaves as the samples brew. Musty/new leather was only detected at the longest brewing time (20 minutes) at 50°C and 70°C. Musty/new leather was detected at all brewing times with 95°C water, and its intensity increased as the time of brewing increased. This finding indicates that the compound responsible for this off-flavour note is only released at high temperature or long time, one possible reason that brewing of green tea is suggested at lower temperatures.

Water temperature

Because most flavour attributes had an interaction among water temperature and length of brewing, only seaweed and straw-like are discussed for water temperature. When green tea was brewed with 50°C or 70°C water, the flavour intensity of seaweed did not change. However, when 95°C water was used for brewing, the intensity of seaweed flavour in the tea was significantly lower than the intensity of tea brewed with 50°C or 70°C water. The intensity of straw-like flavour increased as the water temperature increased.

Length of brewing

The intensity of the seaweed flavour note was the highest when green tea was brewed for 5 minutes. One, 2 and 20 minutes of brewing time of the green tea resulted in a similar intensity for seaweed note, suggesting that the compounds for seaweed flavour take time to become apparent, but then dissipate. The intensity of straw-like flavour did not change with 1 or 2 minute(s) of brewing and then increased to a higher level at 5 and 20 minutes.

Green Tea Products

Bitter, brown, burnt/scorched and astringent were markedly affected by the brewing methods. Generally, green tea brewed at 50°C for 1 minute, at 50°C for 2 minutes and at 70°C for 1 minute had low to moderate intensity for bitterness and other flavour attributes. Green tea brewed at 50°C for 20 minutes, at 70°C for 20 minutes, at 95°C for 5 minutes and at 95°C for 20 minutes had a moderate to high intensity for bitterness and low to moderate intensity for the rest of attributes.

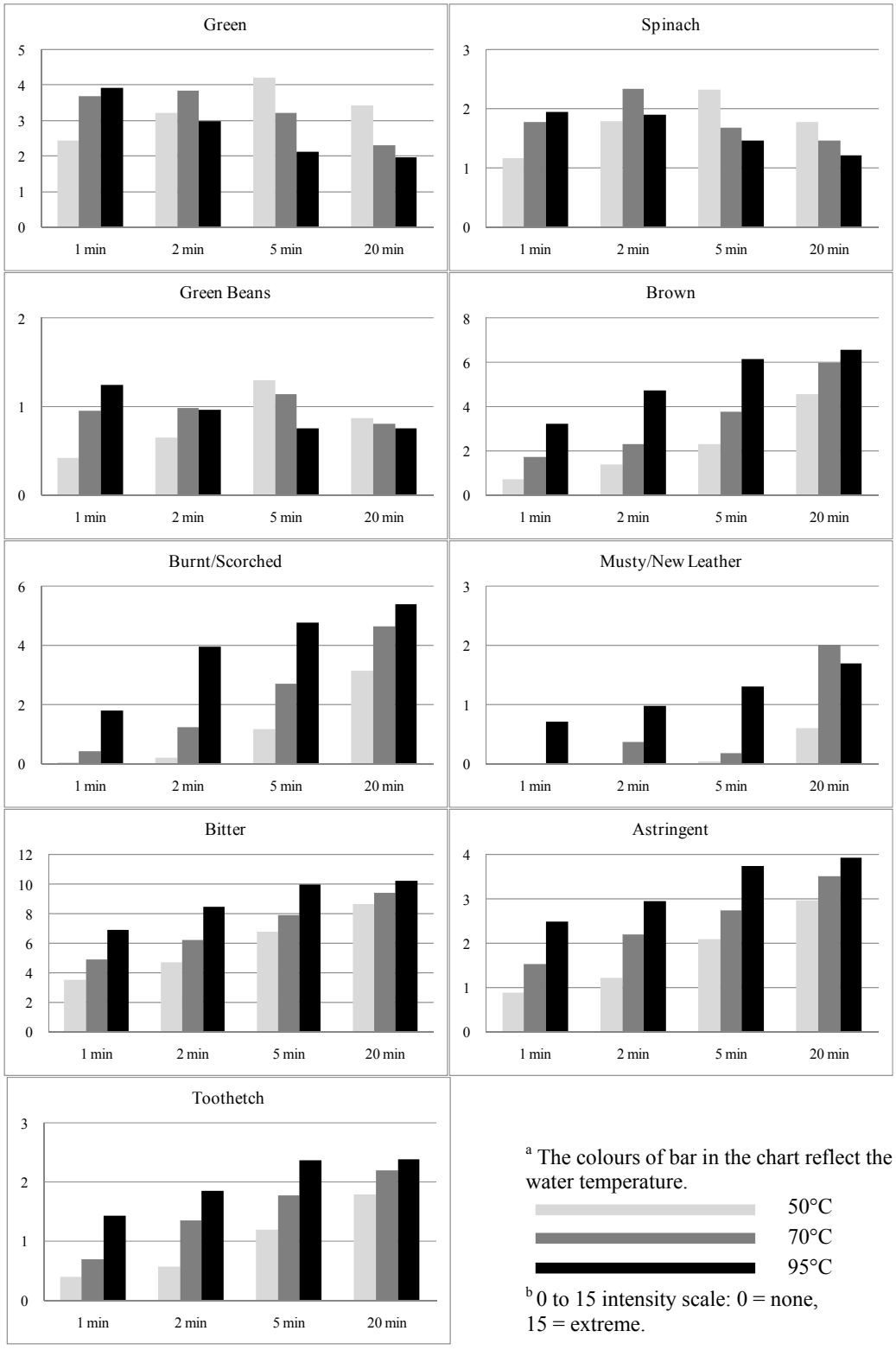


Figure 2. Interaction of Water Temperature[a] by Brewing Time for Green, Spinach, Green Beans, Brown, Burnt/Scorched, Musty/new leather, Bitter, Astringent and Tooth-etch attributes[b].

Table 1. Mean scores of *Ouksu* green tea sample at 12 brewing conditions differing water temperatures and brewing time.

Temperature	50ºC				70ºC				95ºC			
Length of Brew (min)	1	2	5	20	1	2	5	20	1	2	5	20
Green	2.08	3.25	4.42	4.00	3.56	3.81	3.56	2.47	4.64	3.47	2.72	2.47
Asparagus	0.00	0.00	0.50	1.03	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00
Celery	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green beans	0.00	0.00	0.69	0.00	0.56	0.56	1.08	0.00	0.91	0.83	0.00	0.75
Green herb-like	1.06	0.72	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parsley	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.67	0.00	0.00	0.00
Spinach	0.89	1.94	2.83	2.08	1.69	2.69	1.55	1.72	2.75	2.19	2.08	1.14
Brown	0.00	0.92	1.67	4.14	0.86	1.81	3.83	5.64	2.25	4.36	5.75	6.08
Ashy/Sooty	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	1.89
Burnt/Scorched	0.00	0.00	1.03	3.25	0.00	0.75	2.94	4.89	1.56	4.00	4.78	5.81
Citrus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grain	0.00	0.00	0.00	0.61	0.00	0.00	0.00	1.06	0.00	1.33	0.00	0.00
Medicinal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Musty/new leather	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.78	0.00	0.61	2.00	0.00
Nutty	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Seaweed	0.00	0.53	1.25	1.56	0.00	0.00	1.64	0.92	1.73	0.75	1.56	0.81
Straw-like	0.00	0.00	1.50	0.72	0.97	1.25	1.72	2.19	1.53	1.94	1.78	1.75
Tobacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bitter	3.31	5.72	6.72	8.78	4.31	5.86	8.69	9.11	6.61	8.42	10.06	10.11
Astringent	0.00	1.06	1.75	2.50	1.03	1.86	2.83	2.81	2.11	2.69	3.22	3.28
Tooth etch	0.00	0.58	0.97	1.69	0.00	0.78	1.81	1.97	1.47	1.83	2.00	2.11
Sweet aromatics	0.67	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. Mean scores of *Sejac* green tea sample at 12 brewing conditions differing water temperatures and brewing time.

Temperature	50ºC				70ºC				95ºC			
Length of Brew (min)	1	2	5	20	1	2	5	20	1	2	5	20
Green	2.67	3.58	4.67	2.92	3.96	3.89	2.94	2.08	3.86	2.28	1.69	1.44
Asparagus	0.00	0.50	1.19	0.83	0.67	0.81	0.00	0.00	0.81	0.00	0.00	0.00
Celery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green beans	0.67	0.94	1.81	1.25	1.00	1.31	0.92	0.97	1.86	0.75	0.97	0.50
Green herb-like	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parsley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinach	1.72	2.08	2.08	1.64	1.67	2.22	1.89	1.44	1.42	1.42	1.39	0.97
Brown	0.83	1.75	2.83	5.36	2.38	2.89	4.42	6.28	3.97	5.72	6.58	6.97
Ashy/Sooty	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	1.42	0.50	1.08
Burnt/Scorched	0.00	0.00	1.33	3.78	0.00	2.03	3.28	3.72	2.81	4.08	4.81	4.81
Citrus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grain	0.00	0.00	0.00	1.25	0.00	0.00	0.61	0.00	0.92	1.03	0.50	0.00
Medicinal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Musty/new leather	0.00	0.00	0.00	0.00	0.00	0.56	0.00	2.67	0.00	1.28	0.64	1.00
Nutty	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.89	0.56	0.69	0.58	1.78
Seaweed	2.17	2.61	3.33	2.72	3.33	2.64	4.22	2.92	3.22	3.06	3.94	2.00
Straw-like	1.19	1.11	2.06	2.28	1.67	1.94	1.92	2.22	2.22	2.33	2.75	2.14
Tobacco	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	1.06	0.00	2.56
Bitter	3.78	5.03	7.36	8.97	5.38	7.03	8.28	9.50	7.92	8.94	9.69	10.03
Astringent	1.17	1.26	2.06	2.92	1.50	2.36	2.64	3.42	2.17	2.97	3.50	3.83
Tooth etch	0.00	0.53	1.03	1.72	0.50	1.58	1.61	1.99	1.06	1.83	2.31	2.14
Sweet aromatics	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3. Mean scores of *Soon* green tea sample at 12 brewing conditions differing water temperatures and brewing time.

Temperature	50ºC				70ºC				95ºC			
Length of Brew (min)	1	2	5	20	1	2	5	20	1	2	5	20
Green	2.56	2.76	3.53	3.39	3.53	3.83	3.18	2.36	3.31	3.17	1.94	1.94
Asparagus	0.00	0.00	0.00	0.00	0.00	0.89	0.60	0.00	0.00	0.00	0.00	0.00
Celery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green beans	0.58	0.65	1.41	1.19	1.32	1.08	1.44	1.19	0.97	1.31	1.21	1.03
Green herb-like	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Parsley	0.00	0.00	0.00	1.25	0.62	0.00	0.00	0.00	0.75	0.00	0.88	0.50
Spinach	0.89	1.32	2.06	1.61	1.97	2.08	1.62	1.22	1.67	2.11	0.88	1.53
Brown	0.97	1.47	2.47	4.19	1.94	2.28	3.06	6.06	3.42	4.08	6.18	6.68
Ashy/Sooty	0.58	0.00	1.59	1.17	0.00	0.58	0.62	1.81	0.94	1.50	1.47	0.00
Burnt/Scorched	0.00	0.00	1.15	2.39	0.00	0.86	1.85	5.33	0.97	3.75	4.74	5.62
Citrus	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grain	0.00	0.00	0.00	0.81	0.00	0.00	0.91	2.22	0.00	1.28	2.00	0.71
Medicinal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50
Musty/new leather	0.00	0.00	0.00	0.64	0.00	0.00	0.00	2.58	1.39	1.03	1.29	4.03
Nutty	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.58	0.00	0.00	1.74	1.41
Seaweed	1.39	1.74	2.38	1.00	1.53	1.89	1.09	1.75	0.00	0.00	0.76	0.00
Straw-like	0.78	1.35	1.38	1.78	1.59	1.75	2.00	2.00	2.03	1.89	2.26	2.21
Tobacco	0.00	0.00	0.00	1.42	0.00	0.00	0.85	0.64	0.00	0.00	0.00	0.00
Bitter	3.39	3.35	6.18	8.17	4.94	5.78	6.65	9.67	6.17	8.11	10.15	10.53
Astringent	1.25	1.35	2.53	3.50	2.06	2.36	2.74	4.31	3.22	3.17	4.59	4.74
Tooth etch	0.75	0.59	1.62	1.97	1.15	1.69	1.93	2.61	1.76	1.92	2.85	2.94
Sweet aromatics	0.75	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

All three green tea samples had distinct flavours regardless of how they were brewed (Figure 1). *Ouksu* had more green-related attributes but did not have citrus, medicinal, nutty and tobacco flavour in any brewing method (Table 1). *Sejac* had more brown, asparagus and seaweed notes than the other samples and did not present celery, parsley, citrus, medicinal and sweet aromatics (Table 2). The *Soon* product was more astringent and tooth-etching and had more ashy/sooty and musty/new leather flavour than the other samples. Also, the panel did not find celery and green herb-like flavour attributes in the *Soon* samples (Table 3).

Recommendation

Brewing methods using different water temperatures and length of brew result in different flavours in green tea liquor. Consumers may brew green tea using 50-70°C water for 1 to 5 min and have more green-related flavour, lesser brown-related flavour and low to moderate bitterness in their green tea with no off-flavour such as musty/new leather and medicinal. Brewing green tea longer than 5 min and/or using 95°C water may result in stronger brown-related flavour than green-related flavour. Also, brewing green tea with longer than 5 min and/or using 95°C water may result in bitter and astringent tea. In some green tea, brewing at 95°C or longer than 5 min may induce musty/new leather flavour and brewing at 95°C for 20 min may cause off-flavour such as medicinal. Green tea retailers may use this information to recommend proper brewing directions for consumers so that consumers can avoid creating off-flavours while brewing. Ready-to-drink green tea manufacturers may brew green tea at 70°C for 1 or 2 min to obtain a similar flavour profile to green tea brewed using 50°C for 2 or 5 min with no risk of inducing off-flavours during brewing.

Conclusion

The flavour of green tea changed when different brewing methods were used. Green-related flavours are leached promptly and then dissipate. As water temperature increased, bitterness, astringency and tooth-etch increased. At high brewing temperatures, brown flavours overtake green flavour notes that should be present in green tea. Increasing brewing time also provided similar results, depending in part on brewing temperature, with brown flavour, bitter, astringent and tooth-etch intensity increasing as brewing time lengthened. Musty/new leather note was only released at high temperature or long time, which may be a reason why green tea is suggested to brew at lower temperatures. Most green tea in leaf form should be brewed using 50-70°C water for 1 to 5 min. This information can be used to find optimal brewing condition by green tea consumers, green tea retailers and RTD green tea manufacturers depending on what flavour characteristics they desire from green tea.

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