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Effect of Different Brewing Conditions on Sensory Properties of Green Tea: A Tasting Study

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Abstract

Green tea has high catechin content compared to other tea varieties and this feature makes it very important in terms of health. The aim of this study was to evaluate the effect of different brewing parameters on the sensory properties of green tea and to determine the ideal brewing parameters. Brewing parameters were determined as teapot type (chrome-steel, French press and porcelain), brewing type (open and closed), brewing time (3, 5 and 7 min) and brewing water temperature (80, 90 and 95 ℃) and sensory characteristics as color, astringency and flavor. Within the scope of the study, a total of 1890 tea cups (630/1260, control/test) were sensory evaluated and statistically analysed. The color level of green tea brewed in chromium-steel and French press teapots was higher than that brewed in porcelain teapots, and the color and flavor level of green tea brewed with 95 ℃ water was higher than that brewed with 80 ℃ water ($p<0.01$). There was no effect of brewing method and brewing time on color, astringency and flavor of green tea ($p>0.01$). There was a moderate negative linear relationship between color and flavor and a moderate positive linear relationship between flavor and astringency ($p<0.01$). It is thought that the findings will contribute to producers and consumers and scientific studies on the brewing process of green tea.

Keywords: Green tea, brewing conditions, teapot, infusion, sensory properties

Farklı Demleme Koşullarının Yeşil Çayın Duyusal Özellikleri Üzerine Etkisi: Bir Tadım Çalışması

Öz

Yeşil çay diğer çay çeşitlerine göre yüksek kateşin içeriğine sahiptir ve bu özelliği onu sağlık açısından oldukça önemli kılmaktadır. Bu çalışmanın amacı, farklı demleme parametrelerinin yeşil çayın duyusal özellikleri üzerindeki etkisini değerlendirmek ve ideal demleme parametrelerini belirlemektir. Demleme parametreleri; demlik tipi (krom-çelik, French press ve porselen), demleme tipi (açık ve kapalı), demleme süresi (3, 5 ve 7 dk) ve demleme suyu sıcaklığı (80, 90 ve 95 °C) ile duyusal özellikler ise renk, burukluk ve lezzet olarak belirlenmiştir. Çalışma kapsamında toplam 1890 çay bardağı (630/1260, kontrol/test) duyusal olarak değerlendirilmiş ve istatistiksel olarak analiz edilmiştir. Krom-çelik ve French press demliklerde demlenen yeşil çayın renk düzeyi porselen demliklerde demlenenden daha yüksekti ve 95 ℃ su ile demlenen yeşil çayın renk ve lezzet düzeyi 80 ℃ su ile demlenenden daha yüksekti ($p<0,01$). Demleme şekli ve demleme süresinin yeşil çayın rengi, burukluğu ve lezzeti üzerinde bir etkisi yoktu ($p>0,01$). Renk ile lezzet arasında orta düzeyde negatif doğrusal bir ilişki ve lezzet ile burukluk arasında orta düzeyde pozitif doğrusal bir ilişki vardı ($p<0,01$). Bulguların üretici ve tüketicilere ve yeşil çayın demlenme sürecine ilişkin gerçekleştirilecek bilimsel çalışmalara katkı sağlayacağı düşünülmektedir.

Anahtar Kelimeler: Yeşil çay, demleme koşulları, demlik, infüzyon, duyusal özellikler

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1. Introduction

Camellia sinensis is the mother plant of tea, one of the most consumed beverages worldwide (Jia et al., 2021). *Camellia sinensis*, belonging to the Theaceae family, is an evergreen perennial plant that grows in humid climates (Xu et al., 2021). *Camellia sinensis* is transformed into different tea types such as black, green, oolong and white tea according to different processing methods (Başaran, 2020). Black tea and oolong tea are considered as fully fermented and semi-fermented teas, while white and green tea are considered as unfermented tea, respectively (Salman et al., 2022). This study focuses on green tea, which has been consumed for thousands of years.

Green tea is a drink with many health benefits (Sarma et al., 2023). Green tea has a rich polyphenol content, especially catechins, which have high antioxidant properties (Meyer et al., 2023). These antioxidants protect the body against free radicals and strengthen the immune system (Sun et al., 2022). Green tea also has effects that accelerate metabolism and help weight control (Xu et al., 2023). Regular consumption of green tea lowers bad cholesterol (LDL), keeps blood pressure in balance and supports heart health (Brimson et al., 2022). While caffeine in green tea provides mental alertness and L-theanine can reduce stress levels by supporting a sense of relaxation (Dashwood and Visioli, 2025; Ikar and Sable, 2023).

Sensory analysis in tea is of central importance in scientific, industrial and consumer-oriented evaluation processes. When evaluated from a scientific perspective, sensory analysis reveals the relationship between the chemical composition of tea and perceptual characteristics such as taste, aroma and color, and provides the opportunity to objectively evaluate the effect of tea processing techniques or growing conditions on its sensory profile (Ruiz-Capillas and Herrero, 2021). Scientific studies in this context provide data, especially for the development of new tea varieties and the definition of tea quality criteria. From an industrial perspective, sensory analysis is an indispensable part of product standardization and quality control processes (Lee et al., 2018; Sipos et al., 2021). In this way, producers can both ensure consistency between the same production batches and develop product profiles suitable for different markets. From a consumer perspective, sensory analysis enables the optimization of sensory characteristics such as taste, smell and visuality, which directly affect product taste and preferences (Liu et al., 2018; Yang and Lee, 2019).

Green tea brewing methods vary significantly from country to country, depending on the type of tea and cultural habits. In Japan, green tea is brewed at low temperatures of 60–70°C and for a short time (1–2 minutes) (Okubo et al., 2018), while in China, green tea is brewed in glass or porcelain containers with hot water at around 80–85°C (Li et al., 2019). In Morocco, green tea is brewed at high temperatures with fresh mint and plenty of sugar, and the tea is strained several times to allow it to come into contact with oxygen (Boulila et al., 2021). This diversity shows that green tea is not only a beverage but also a ritual that carries a unique cultural value in each society.

Türkiye ranks fourth in the world in tea production and first in tea consumption (Food and Agriculture Organization, 2020). In Türkiye, tea is harvested in 4 provinces in the Black Sea Region (Rize, Giresun, Artvin and Trabzon) between May and October.

According to 2024 data, 1,440 thousand tons of fresh tea was processed in Türkiye and approximately 275 thousand tons of dry tea was produced (URL-1, 2024). There is no common brewing procedure since how tea brewing should be done varies according to geography, culture and individual behavior (Basaran et al., 2024). However, brewing procedure is known to have an effect on the taste, appearance, flavor and color of green tea (Guo et al., 2024; Tan et al., 2023; Yu et al., 2021). Because the diffusion rate of chemical components in tea is not the same under different brewing conditions and this will affect the sensory properties of tea (Li et al., 2022; Wang et al., 2024). The aim of this study was to investigate and evaluate the effect of different brewing conditions on the sensory properties (color, astringency and flavor) of green tea.

2. Materials and Methods

2.1 Green Tea Samples

In this study, 3 brands of green tea produced by tea enterprises operating in Rize city and known to be frequently consumed by the society were included. Each sample was purchased from the factory in its original packaging (500 g). All samples were stored at room temperature and in a dark environment.

2.2 Establishment of a Tea Tasting/Research Team

In the literature review, a common tea brewing procedure accepted by all segments for green tea could not be reached. Therefore, the brewing procedure for green tea was determined by the research team consisting of 3 people. Green tea tastings were carried out by 7 panellists who had previously received tea tasting training (certified) and were actively working in the tea sector.

2.3 Brewing Parameters

The equipment commonly used in green tea brewing in Türkiye (chrome-steel (Liza, Türkiye), porcelain (Kütahya porcelain, Türkiye) or French press (Comprox Cambu, Türkiye) consists of one piece. In this study, similar equipment was preferred considering the consumption habits of individuals and the same equipment was used in all brewing processes. 2 L of ultrapure water was boiled on a stove providing continuous heat (≈95°C). From the boiled pure water, 100 mL was transferred to the equipment and poured after shaking well. Then 500 mL of boiled distilled water at 80, 90 and 95 °C was added to the teapot and 4 g of green tea (powder) sample was weighed on it. Brewing in chromium-steel and porcelain teapots was also carried out with the teapot mouth open and closed. Brewing was carried out for 3, 5 and 7 min. At the end of the time, 80 mL of the brewed green tea was filtered with the help of a strainer and taken into a glass for tasting. The brewing procedure is shown in Figure 1.

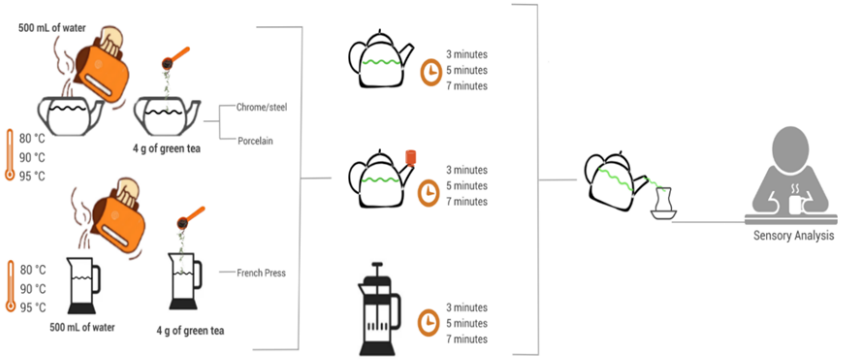

Figure 1. Brewing parameters determined for green tea

2.4 Sensory Analyses

Tasting analyses were carried out in a kitchen located in the Recep Tayyip Erdoğan University campus, in a noise-free environment equipped with sufficient and necessary equipment for brewing tea and illuminated with daylight. Tasting analyses of brewed green teas were carried out using a method belonging to a private company (Brand C). In the method, sensory evaluation of green tea is carried out according to color, astringency and flavor (taste and smell) parameters and each parameter is evaluated on 1.4, 1.4 and 1.4 points, respectively. Green teas from three brands were brewed according to the same procedure. Then, sensory analyses of Brands A and B were performed by the panelists according to the sensory characteristics of Brand C. In sensory analyses, Brand A and B were determined as test groups and Brand C as control group. Tea brewing of each brand was carried out in 2 replications. Panelists recorded their scores using the tasting forms given to them beforehand.

2.5 Statistical Evaluation

The study data were analyzed using the R software program (RStudio 4.4.2, R Foundation). While evaluating the data, descriptive statistics (median, minimum, and maximum) were given for numerical variables. The data were evaluated using the Mann Kruskal Wallis Test, Whitney U Test, and Anova Test. The differences between the groups were examined using the Bonferroni Test, Student's t test, and Tukey test. Principal component analysis (PCA) was used to describe the correlations among both the sensory and chemical profiles with varying brewing parameters. The degree of non-causal relationships between two numerical variables was examined using Spearman's rho correlation coefficient. $p<0.01$ was considered statistically significant.

3. Results and Discussion

Within the scope of the study, a total of 45/90 (control/test) tea brewings (teapot) were carried out from green teas belonging to 3 different brands. The values of color, astringency and flavor parameters in brewed green teas are shown in Table 1.

According to teapot type; the color level of green tea brewed in chrome-steel and French press teapots was statistically significantly higher than the color level of tea brewed in porcelain teapot ($p<0.01$). There was no statistically significant difference between the astringency and flavor parameters of green tea according to teapot type ($p>0.01$). It is thought that the different thermal conductivity coefficients of the materials used in the production of different teapots are effective on the color level. In green teas brewed in teapots with high thermal conductivity coefficient (such as chromium-steel), the passage of compounds that have an effect on color formation may have been faster. As a matter of fact, Liao et al. (2018) reported that different teapot types can affect the taste of tea. In the study examining the effect of various teapot types on the sensory properties of different tea varieties, it was reported that the tea brewed in tin teapots exhibited a fresher taste, so it was suitable for brewing green tea and white tea. In the same study, it was explained that the sweetness and thickness of the tea brewed with porcelain tea set increased, so it is more suitable for brewing black tea (Guo et al., 2024).

Table 1. Sensory evaluation of green tea according to brewing parameters

Parameters	Subparameters	Number of brewing	Color	Astringency	Flavor
			Median (Min.− Max.)	Median (Min.− Max.)	Median (Min.− Max.)
Teapot type	Chrome-steel	36	1.25[a] (1.10−1.40)	0.70[a] (0.60−0.90)	0.70[a] (0.60−0.90)
	Porcelain	36	1.21[b] (1.00−1.40)	0.70[a] (0.60−0.80)	0.70[a] (0.60−0.80)
	French press	18	1.33[a] (1.30–1.40)	0.70[a] (0.60−0.80)	0.70[a] (0.60−0.90)
Teapot spout	Open	36	1.21[a] (1.10–1.40)	0.70[a] (0.60–0.80)	0.70[a] (0.60–0.90)
	Close	36	1.36[a] (1.00−1.40)	0.70[a] (0.70–0.90)	0.70[a] (0.60–0.80)
Brewing time	3 min	30	1.20[a] (1.00−1.40)	0.70[a] (0.70−0.80)	0.70[a] (0.60−0.80)
	5 min	30	1.20[a] (1.00–1.40)	0.80[a] (0.60−0.90)	0.70[a] (0.60−0.90)
	7 min	30	1.20[a] (1.10−1.40)	0.70[a] (0.50−0.80)	0.70[a] (0.60−0.80)
Brewing water temperature	95 ℃	30	1.36[a] (1.20−1.40)	0.80[a] (0.60−0.80)	0.80[a] (0.60−0.90)
	90 ℃	30	1.25[b] (1.10−1.30)	0.70[a] (0.60−0.90)	0.70[b] (0.60−0.80)
	80 ℃	30	1.17[c] (1.00−1.30)	0.70[a] (0.60−0.90)	0.70[b] (0.60−0.70)

Different letters in the same group show statistically significant differences ($p<0.01$). Min: Minimum, Max: Maximum.

Within the scope of the study, green tea was brewed by leaving the ends of chrome-steel and porcelain teapots, except for the French press, open and closed. However, no statistically significant difference was found between the color, astringency and flavor parameters of green tea according to the brewing method ($p>0.01$).

Brewing time is a very important factor in terms of the passage of compounds in tea leaves that have an effect on the sensory properties of tea (Pastoriza et al., 2017; Takım and Aydemir, 2025). However, in this study, no statistically significant difference was found between the color, astringency and flavor parameters of green tea according to the brewing time ($p>0.01$). It is thought that the selected brewing times (3, 5 and 7 min) being both short and close values are effective on the findings. In short brewing times, the passage of the compounds that will affect the color, astringency and flavor parameters of green tea to the brew may have been both limited and at similar rates. In the literature, it has been reported that many parameters such as color, brightness, astringency and flavor of tea can vary significantly in parallel with the increase in brewing time (Cao et al., 2021; Polat et al., 2022; Yu et al., 2021). Green teas were reported to have the highest sensory scores for infusion color, taste, aroma and overall acceptability at 3- and 5-minutes brewing times (Saklar et al., 2015). It was reported that brewing 11 different tea types including green tea for 5, 10 and 15 min significantly affected the level of antioxidant compounds (Winiarska-Mieczan and Baranowska-Wójcik, 2024).

According to brewing temperature, the color level of green tea brewed with 95℃ water was significantly higher than the color level of green tea brewed with 90 and 80℃ water, and the color level of green tea brewed with 90℃ water was significantly higher than the color level of green tea brewed with 80℃ water ($p<0.01$). The flavor level of green tea brewed with 95 ℃ water was statistically significantly higher than the flavor level of green tea brewed with 90 and 80 ℃ water ($p<0.01$). The temperature of brewing water

is one of the most important factors affecting the sensory quality of tea (Jin et al., 2019; Saklar et al., 2015;). As a matter of fact, in this study, the color level of green tea increased as the temperature value of the brewing water increased, and the findings are consistent with the literature (Pastroriza et al., 2017; Yu et al., 2021). The reason for this situation is that with the increase in the temperature value of the brewing water, the compounds in the green tea leaf, which may affect the color and flavor level, pass through the brew at a higher level compared to other temperature values. Yu et al. (2021) and Zhao et al. (2022) reported that the level of a large number and variety of aroma compounds that can affect the flavor increases in parallel with the increase in brewing water temperature. Saklar et al. (2015) reported that sensory scores of green tea were very low in 30 and 45 min brewing at 85 and 95 °C due to bitter taste and dark color. The main reason for this situation is long brewing times. Jin et al. (2019) reported that catechins reached the maximum level in green tea brewed at 95 °C (approximately 10 min).

Figure 2 (a-d) shows PCA plots indicating the levels of color, astringency and flavor detected at different brewing parameters. Points represent observations (tea samples), arrows represent color, astringency and flavor levels, and colors represent different brewing parameters. After applying PCA, the first principal component (PC1) explained 65.8% of the total variance and the second principal component (PC2) explained 26.0% of the variance. Both PC1 and PC2 explained a total of 91.8% of the variance.

Tea samples brewed with different teapot spouts (open and closed), and brewing time (3, 5 and 7 minutes) did not exhibit a clear separation on PC1 and PC2 (Figure 2(b, c)). Tea samples brewed with french press were separated from tea samples brewed porcelain on PC1, mostly displaying lower PC1 scores (Figure 2(a)). Brewing tea using a French press is associated with higher color parameter values, indicating a tendency to produce teas with a darker color. Porcelain-brewed tea samples align most with flavor vector, indicating a tendency to produce teas with enhanced flavor intensity. Steel-brewed tea samples indicate a balanced profile, contributing moderately to taste properties both flavor and astringency.

Tea samples brewed at 95 ℃ were separated from tea samples brewed at 80 and 90 ℃ on PC1 mostly displaying lower PC1 scores (Figure 2(d)). Tea samples brewed at 95 ℃ is associated with higher color parameter values, indicating a tendency to produce teas with a darker color. Tea samples brewed at 80 ℃ align most with flavor vector, indicating a tendency to produce teas with enhanced flavor intensity. Tea samples brewed at 90 ℃ indicates a balanced profile, contributing moderately to both flavor and astringency.

Overall, PC1 likely reflects a color–flavor trade-off, with French press brewing at 95 °C favoring color, and porcelain brewing at 80 °C favoring flavor. PC2 captures a balance between astringency and flavor, with steel teapots and brewing at 90 °C. Since group means are more clearly separated on the PCA plot by brewing temperature than by teapot type, this suggests that temperature has a stronger influence on chemical extraction, such as color and flavor. As a result, PCA analysis indicates both teapot type and temperature interact with sensory properties.

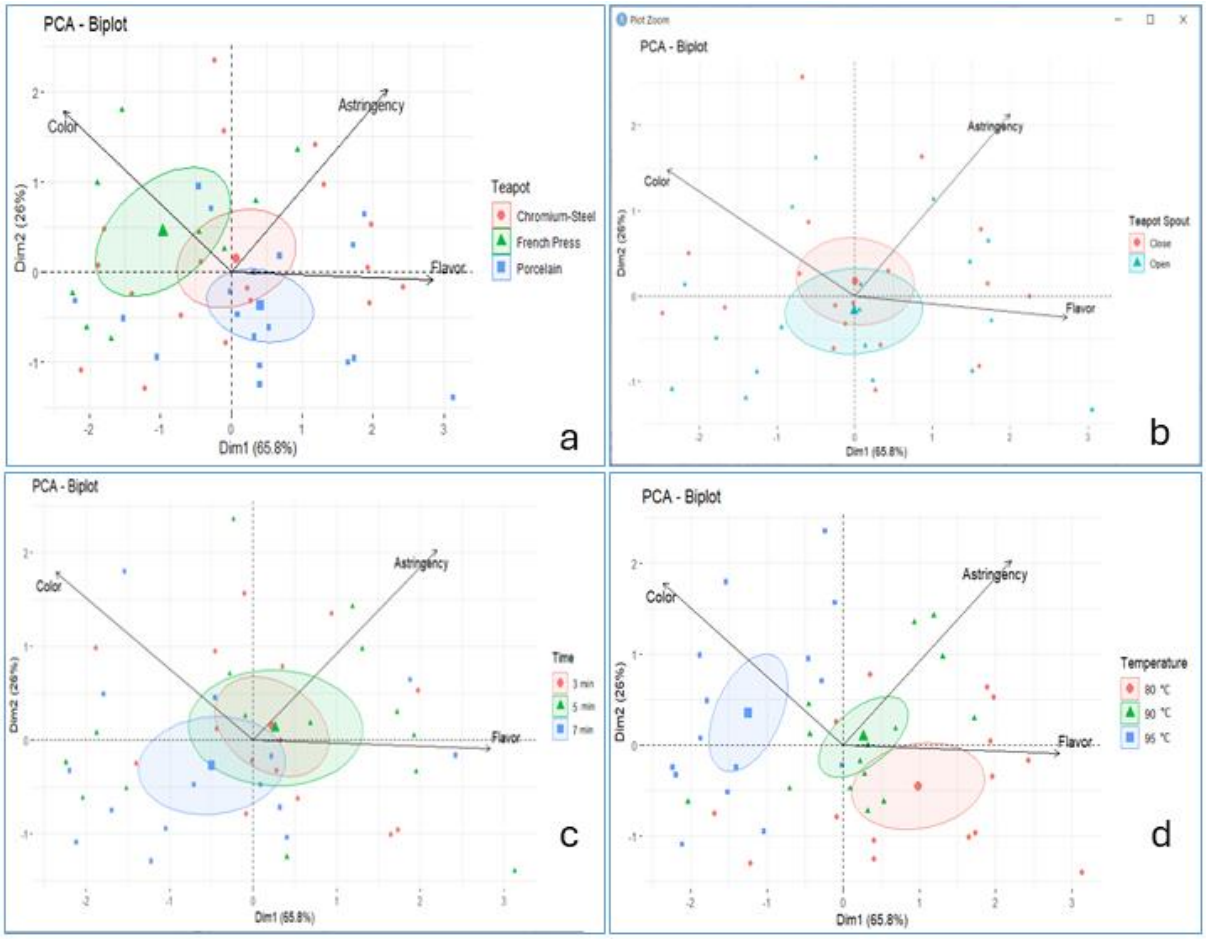

Figure 2. PCA analysis of sensory parameters. PCA plots according to teapot type (a), teapot spout (b), brewing time (c), brewing temperature (d).

There was a moderate negative linear relationship between color and flavor (r=-0.6; p=0.0004) and a moderate positive linear relationship between flavor and astringency (r=0.66; p=0.002). No relationship was found between color and astringency (r=-0.25; p=0.09). Wang et al. (2014) reported a positive correlation between flavor and astringency of black tea (Figure 3).

In green tea, color, astringency, and flavor are three basic sensory properties that are directly related to each other. Each of these properties is determined by the chemical composition of the tea and the brewing conditions, and together they create the overall flavor profile of the tea. The color of green tea affects not only visual perception but also flavor and astringency. Astringency and flavor become more pronounced as the color increases. Astringency creates a feeling of dryness and friction in the mouth. This sensation usually causes the tea to be perceived as more "thick" or "harsh." As astringency increases, sweetness and smoothness decrease. Flavor is shaped by aromatic volatile compounds, as well as basic tastes such as sweetness, bitterness, and umami. Color and astringency affect the perception of these flavors. For example, darker and more astringent teas are generally perceived as less sweet and more bitter. In addition, perception of sweet flavors may be suppressed in cases of intense astringency.

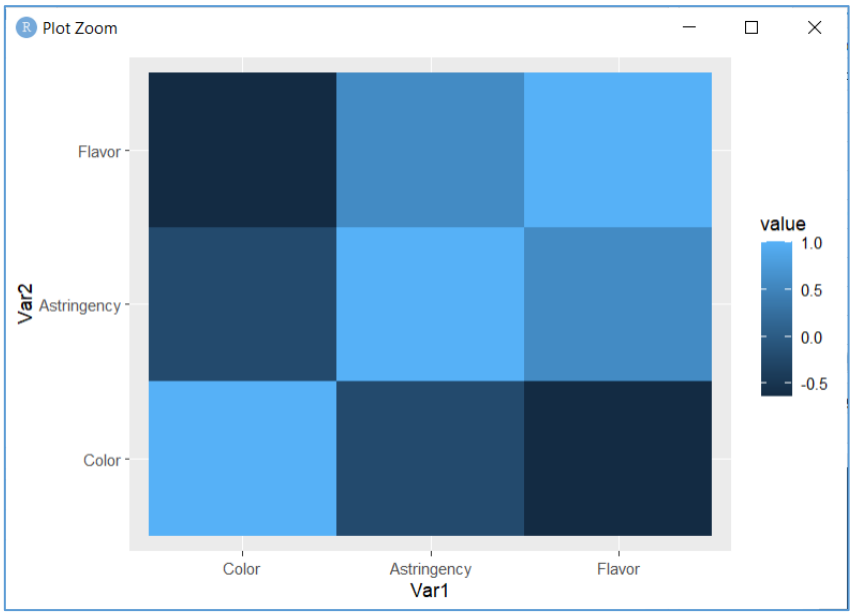

Figure 3. Correlation relationship of sensory parameters

4. Conclusions

In this study, sensory properties of green teas, which are the most consumed after black tea in the world and known to have many health benefits, were evaluated by trained tasters under different brewing conditions. It was found that teapot type was effective on color and brewing water temperature was effective on color and flavor. No brewing parameter affecting astringency was found. It was determined that brewing green tea in a chrome-steel or French press at 95 ℃ for 5 min gave the best results in terms of color, astringency and flavor. In this context, these results obtained in Turkish green teas are largely similar to the literature.

Green teas produced in Türkiye and belonging to the most preferred brands by consumers were included in this study. Therefore, the results obtained cannot cover all green teas produced in Türkiye. In addition, the composition of tea may vary depending on many factors such as geography, climate and production conditions. More research should be conducted on the compounds affecting the sensory properties and health effects of green tea.

Author Contribution

Abanoz, Y.Y: Investigation; Methodology; Formal analysis; Visualization, **Boyraz, A**: Formal analysis; Investigation; Methodology, Visualization; Writing-original draft; review & editing, **Basaran, B**: Investigation; Methodology; Formal analysis; Software; Visualization; Writing-original draft; review & editing.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Ethical Standards

This study was conducted under the "Principles of the Declaration of Helsinki". Prior to the study, written permission was obtained from Recep Tayyip Erdogan University Research Ethics Committee [Decision No: 2024/354]. In the study, the ethical principle of 'informed consent' was fulfilled and voluntariness was taken as a basis. All information of the participants was kept in accordance with the 'confidentiality principle' throughout the study.

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