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Effects of tea and coffee on tooth discoloration

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Abstract

Tooth discoloration because of dietary habits is a serious concern, particularly from tea and coffee consumption. This study investigated the effects of these beverages on tooth discoloration, focusing on their key chemical components. Bovine enamel specimens were immersed in green and black tea samples and Arabica and Robusta coffee samples for 1–72 h. High-performance liquid chromatography analyzed catechins, theaflavins, and chlorogenic acids, while spectrophotometry measured discoloration. Multiple regression analysis (significance at $p < 0.05$) revealed that all beverages caused significant tooth discoloration, with black tea showing the most pronounced effect because of its theaflavin content.

Keywords: catechins; chlorogenic acids; coffee; tea; theaflavins; tooth discoloration

Introduction

Tooth discoloration is a common esthetic concern affecting people of all ages. Among the various factors contributing to this condition, dietary habits, especially the consumption of certain beverages, play a significant role. Tea and coffee, two of the most widely consumed beverages worldwide, are frequently associated with teeth staining.

Tea, the second most-consumed beverage globally, is predominantly consumed as green tea in Japan and China, while black tea is more popular in Western countries (Ahmed *et al.,* 2018, Suzuki *et al.,* 2016). Both green and black tea varieties are derived from the leaves of *Camellia sinensis* (Filippini *et al.,* 2020, Namita *et al.,* 2012). The main difference between these two tea types lies in their processing methods. Green tea undergoes minimal oxidation, while black tea is produced through extensive oxidative processes (Filippini *et al.,* 2020). This difference in oxidation leads to variations in the chemical composition of these beverages. Consequently, they have varying polyphenol contents, which lead to different chromogens that may cause tooth discoloration (Leung *et al.,* 2001). The primary chromogens in green tea are catechins whereas in black tea, theaflavins predominantly arise from the oxidation of catechins (Li *et al.,* 2013, Tanaka and Kouno, 2003). Although previous

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studies observed tooth discoloration because of tea consumption, particularly black tea, comprehensive analyses linking detailed chemical compositions to tooth discoloration are still lacking (Hardini *et al.,* 2022, Karadas *et al.,* 2014, Panahandeh *et al.,* 2023).

Coffee is brewed from the seeds of Coffea plants and primarily consists of two varieties: Arabica (*Coffea arabica*) and Robusta (*Coffea canephora*) (Mehrabi and Lashermes, 2017). Coffee contains high levels of chromogens and melanoidins, both formed during roasting process (Nunes *et al.,* 2012). Melanoidins and chlorogenic acids (CGAs) in coffee cause significant tooth discoloration by binding to the enamel and potentially eroding its surface, leading to extrinsic stains that range from yellow to dark brown (Kim *et al.,* 2024b, 2024d). Additionally, factors, such as frequency and manner of consumption, type of beans, and level of roasting, can also influence the extent of staining (Kim *et al.,* 2024d).

Despite more extensive studies on coffee staining than on tea-related tooth discoloration, the specific compounds responsible for staining in tea and coffee remain inadequately elucidated (Al Khalifah and Radwan, 2024; Côrtes *et al.*, 2013; Kim *et al.*, 2024b; Pratomo *et al.,* 2018). Previous studies often failed to present detailed information on the concentration of individual components, accurately measured using methods such as high-performance liquid chromatography (HPLC). Therefore, a thorough comparison of the chemical constituents of green and black tea types, and Arabica and Robusta coffee is necessary. Analysis of how these specific constituents interact with dental enamel using appropriate analytical techniques can help consumers and dental professionals to ultimately make informed decisions.

The purpose of this study was to investigate the effects of tea and coffee consumption on tooth discoloration by analyzing their chemical compositions, interactions with dental enamel, and implications for dental esthetics. The null hypothesis tested was that no significant relationship exists among the levels of absorbance, theaflavin, catechins, chlorogenic acids (CGAs), and tooth discoloration. Through quantitative analysis of such components and multiple regression analysis of the results, this study aimed to identify the beverage that poses a greater risk for tooth discoloration and uncover the underlying factors for these differences.

Materials and Methods

Tea Preparation (HPLC)

Tea preparation for extraction was conducted according to the international standard ISO 14502-1, 2005. Dried green (Twinings Gunpowder [GP] and Pure Sencha [PS]) and black (Twinings English Breakfast [EB] and Earl Grey [EG]) tea leaves were finely crunched. Each tea type, 0.20 ± 0.001 g, was weighed and transferred into 10-mL test tubes. Then, 5.0 mL of 70% (v/v) methanol was added to test tubes and mixed using a vortex mixer for 30 s. The mixture was extracted in a water bath at 70°C for 5 min. The mixture was then vortexed for 30 s and left in water bath for additional 5 min. The supernatant was collected and centrifuged for 10 min at 3,500 rpm. This procedure was repeated twice, and the extracts were pooled. The mixtures were filtered through a 0.2-μm filter (Advantec, Tokyo, Japan) and transferred to HPLC vials for analysis.

Green tea: analysis of catechins by HPLC

Standard solutions of epigallocatechin gallate (EGCG), epigallocatechin (EGC), epicatechin (EC), and epicatechin gallate (ECG) (Sigma Aldrich, St. Louis, MO, USA) were prepared to quantify catechins in green tea. A stock solution was prepared by dissolving 10 mg each of EGCG, EGC, EC, and ECG in 10 mL of methanol. Then, 1-, 3-, 5-, and 7-mL stock solution was placed in separate test tubes, each brought to a final volume of 10 mL with methanol. The mobile phase consisted of water and acetonitrile (87:13) with 1% formic acid. A flow rate of 2 mL/min was maintained, and the acquisition wavelength was set at 210 nm. A reverse-phase C18 column (4.6 × 150 mm, 5 μm; Agilent, Santa Clara, CA, USA) was used for all HPLC analyses.

Black tea: analysis of catechins and theaflavins by HPLC

Standard solutions of catechins (EGCG, EGC, EC, and ECG) and theaflavin (all from Sigma Aldrich) were prepared by dissolving 10 mg in 10% acetonitrile. Then, 1-, 3-, 5-, and 7-mL stock solution was added to separate test tubes, each diluted to a final volume of 10 mL with 10% acetonitrile. Simultaneous determination of catechins and theaflavins in black tea was performed using the methods described by Ai *et al.* (2024). A flow rate of 1 mL/min was maintained, and the acquisition wavelength was set at 280 nm. A gradient was established using mobile phase A (0.1% formic acid in acetonitrile; Sigma Aldrich), beginning at 0% and progressing through 6%, 10%, 20%, 30%, 50%, and 55%, alongside mobile phase B (1% formic acid in water).

Specimen preparation and selection

Methods for preparing specimens and coffee were consistent with those used in previous studies (Kim *et al.,* 2023, 2024a, 2024c). To prepare tooth enamel specimens, bovine central and lateral incisors were obtained from the

Korean Traditional Market in Seoul and stored at –20°C until used. Only central and lateral incisors from the lower jaw were used, excluding any with cracks or caries. Before modification, the teeth were kept at room temperature. Using a bench drilling machine (YDM-13 mm; Yongsoo Precision, Daegu, South Korea) equipped with a cylindrical diamond core (⌀10 × ⌀8 mm), 8-mm diameter holes were drilled through the center of each tooth with water applied to prevent overheating. The drilled teeth were then mounted on custom-made acrylic rings (⌀30 × ⌀12 × 4 mm) using self-curing resin (ASCP3000500; Vertex-Dental, Soesterberg, the Netherlands). The specimens were polished with LaboPol-5 grinding and polishing machine (Struers, Copenhagen, Denmark) using silicon carbide papers (#220, #600, and #1200; SiC paper, R&B, Daejeon, South Korea) to maintain the integrity of enamel layer without exposing the dentin. Thickness of specimens was measured with a digital micrometer (CD67-S15PM; Mitutoyo, Kawasaki, Japan) after each grinding session to ensure consistency.

Specimens were chosen according to predefined criteria, requiring a Vickers Hardness Number (VHN) of ≥250 and an L* value of 75±1. The VHN was measured using Vickers hardness tester (HM-220; Mitutoyo, Tokyo, Japan) to confirm that the specimens were primarily composed of enamel. Baseline colors were measured in reflectance mode using a spectrophotometer (Ci7600; X-rite Pantone, Grand Rapids, MI, USA).

Coffee preparation

Arabica (Ethiopia Yirgacheffe) and Robusta (Vietnam) beans from Greenearth Coffee (Gyeonggi-do, South Korea) were medium-roasted at 210°C for 20 min using MK-301 roaster from RAF, China. The roasted beans were then coarsely crunched using a BCG-740All grinder (Beancruise, Seoul, South Korea). The crunched coffee (15 g) was placed in a drip coffee maker (model LCZ1002WT; Lacuzin, Seoul, South Korea) containing 250 mL of distilled water. The brewed coffee was transferred to a plastic container to immerse tooth specimens, reserving a small portion for CGA HPLC analysis and absorbance measurements.

CGA HPLC analysis

The most common CGA isomers (3-CQA, 5-CQA, and 4-CQA) were used to assess CGA content in coffee solutions. Standards were obtained from Sigma Aldrich. Both standards and coffee extractions were analyzed using an HPLC photodiode array detector (HPLC YL 9100-PDA; Youngin Chromass, Gyeonggi, South Korea) and the YL-Clarity software, in accordance with DIN 10767 guidelines. A gradient consisting of 90% mobile phase A (acetonitrile; Sigma Aldrich) and 10% mobile phase B (1% phosphoric acid; Sigma Aldrich) was applied at a flow rate of 1.0 mL/min. The coffee solutions were centrifuged at 10,000 rpm for 10 min at 4°C. The resulting supernatant was then filtered through a 0.2-µm filter (Advantec, Tokyo, Japan) and transferred to HPLC vials for analysis.

Absorbance measurement

Pigment concentrations in the beverages were estimated by measuring the absorbance of supernatants at a wavelength of 416 nm using a Hidex Chameleon spectrophotometer (Hidex Oy, Turku, Finland).

Tea and coffee: tooth immersion

For the tooth immersion experiment, 5 g of loose tea leaves were immersed in 250 mL of boiling water for 3 min, resulting in a tea concentration of 20 g/L. Coffee was prepared using the method described for HPLC analysis, yielding a concentration of 60 g/L. The solutions were then transferred to water baths set at a constant temperature of 50°C. In all, 60 tooth specimens were divided into six batches, each immersed in either tea or coffee solutions at a set temperature of 50°C. The baseline measurements were recorded before immersion and subsequently after 1, 3, 9, 24, 48, and 72 h of cumulative immersion. Color differences (ΔE_{00}) were calculated using the CIEDE2000 formula, based on L*, a*, and b* values measured from the Commission Internationale de l'Éclairage Lab* (CIELAB) color space:

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)}$$

Statistical analysis

A multiple regression analysis was conducted using Python 3.10.12.

Results

The analysis aimed to determine the impact of various compounds found in beverages, such as green tea catechins, black tea theaflavins, CGA in coffee, and overall tea and coffee absorbance, on tooth discoloration, measured as ΔE_{00} (Figure 1). Catechins (EGC, EC, EGCG, and ECG) were found in both green and black tea types,

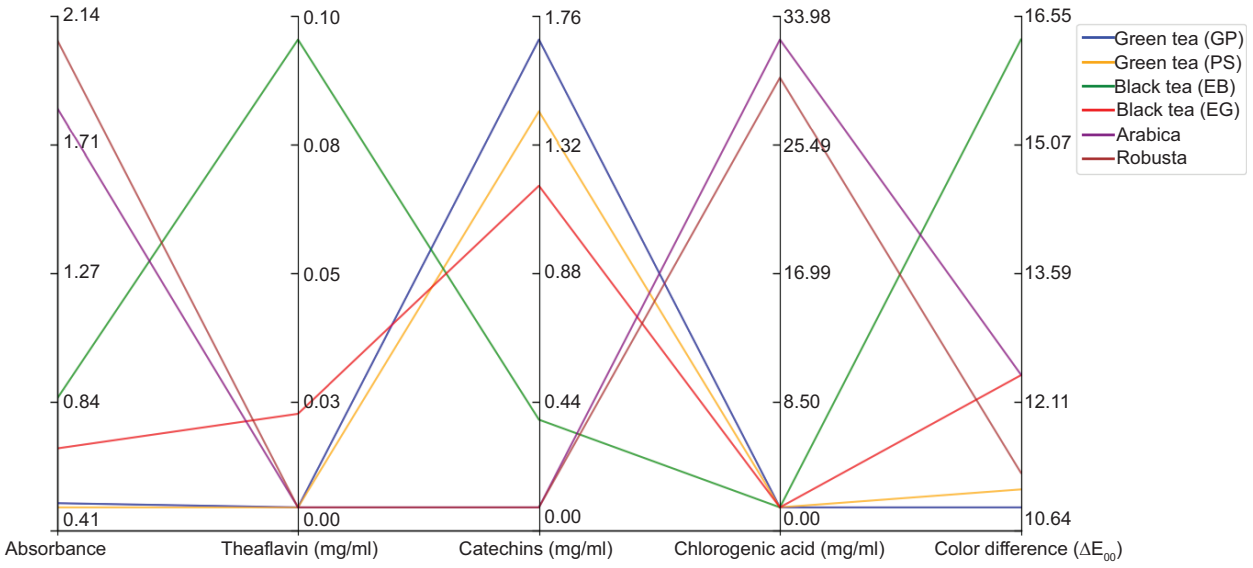

Figure 1. Absorbance, theaflavin content, catechins, CGAs, and color difference for four tea types and two coffee types. Each line represents a different beverage type. GP: Twinings Gunpowder, PS: Pure Sencha, EB: English Breakfast, EG: Earl Grey.

with lower concentrations in black tea. Theaflavin was present in black tea, with EB tea containing a higher level of theaflavin, compared to EG tea. Both Arabica and Robusta coffee varieties contained the same amounts of CGAs. Absorbance was higher in coffee variants, although the difference in maximum wavelength between tea and coffee must be considered.

The multiple regression analysis showed a strong positive relationship between theaflavins and ΔE_{00} ($p = 0.05$), while other variables exhibited a weaker positive relationship with ΔE_{00} ($p > 0.05$) (Table 1). Analyzing impact on tooth discoloration, absorbance values showed no consistent correlation with ΔE_{00}. Robusta coffee showed the highest absorbance at 2.14 ± 0.05 but had the second lowest ΔE_{00} of 11.07 ± 3.29 (Tables 2 and 3). Black tea (EB), which exhibited the greatest discoloration at 15.73 ± 2.99 after 72 h of immersion, had an absorbance of 0.81 ± 0.03, indicating that absorbance alone may not reliably predict discoloration.

For catechins, the highest concentration was 1.76 in Green tea (GP), corresponding to a ΔE_{00} of 10.64 ± 4.23. Green tea (PS), despite having lower catechin content, showed a higher ΔE_{00} of 11.27 ± 2.82, indicating an inconsistent impact. High levels of CGA did not necessarily lead to higher tooth discoloration, as indicated by CGA values of 31.22 ± 0.81 and 33.98 ± 0.47, which matched to the ΔE_{00} values of 11.07 ± 3.29 and 12.31 ± 4.24, respectively (Table 3).

In terms of acceptability and perceptibility thresholds of color differences, it is generally accepted that a ΔE_{00} value below 1.8 is considered acceptable and below 0.8 is imperceptible, meaning the color change is not noticeable to the human eye if $\Delta E_{00} < 0.8$. In this study, all ΔE_{00} values exceeded the perceptibility threshold after 1 h of immersion, indicating noticeable tooth discoloration. Black tea (EB) showed maximum discoloration after 72 h of immersion and discoloration took place more rapidly than all other groups. Even after 1 h of immersion, its ΔE_{00} value was twice that of other beverages.

The data suggested that all tested compounds (absorbance, theaflavins, catechins, and CGAs) contributed to significant tooth discoloration, as indicated by ΔE_{00} values exceeding the perceptibility threshold. The relationships between individual compounds and the extent of discoloration were inconsistent, suggesting that various factors could affect tooth discoloration.

Discussion

The study's findings led to the rejection of null hypothesis, confirming the presence of significant differences in tooth discoloration caused by the beverages tested. Repeated exposure to all beverages caused significant tooth discoloration over time. The immersion time was extended for the experiment, but even 1 h of immersion in these beverages led to visible tooth discoloration.

Although catechins are generally not regarded as potent staining substances, the evidence clearly demonstrated tooth discoloration resulting from exposure to green tea. After 72 h of immersion, significant tooth discoloration was observed, demonstrating that green tea could stain despite its low pigmentation, as evidenced

Table 1. Regression analysis results.

Variables	Coefficient	Standard error	*t*-value	*p*-value	95% Confidence interval (95% CI)
Intercept(ΔE_{00})	13.52	0.91	14.80	0.04	1.91–25.13
Absorbance	−1.29	0.81	−1.60	0.36	−11.57–8.98
Theaflavin	12.96	1.04	12.48	0.05[a]	−0.23–26.16
Catechins	−1.25	0.42	−3.01	0.20	−6.52–4.02
CGA	0.03	0.03	0.93	0.52	−0.34–0.39

CGA: chlorogenic acid. [a]Statistically significant.

Table 2. Content of catechins, theaflavins, and total chlorogenic acids (CGAs) in each beverage.

Beverage	EGC (mg/mL)	EC (mg/mL)	EGCG (mg/mL)	ECG (mg/mL)	Theaflavin (mg/mL)	Total CGAs (mg/mL)	Absorbance	pH
Green tea (GP)[a]	0.38 ± 0.13	0.08 ± 0.02	0.85 ± 0.18	0.45 ± 0.03	-	-	0.42 ± 0.01	7.93
Green tea (PS)[b]	0.31 ± 0.01	0.08 ± 0.01	0.66 ± 0.04	0.44 ± 0.05	-	-	0.41 ± 0.01	7.89
Black tea (EB)[c]	0.06 ± 0.02	0.06 ± 0.01	0.19 ± 0.02	0.02 ± 0.01	0.10 ± 0.02	-	0.81 ± 0.03	5.81
Black tea (EG)[d]	0.22 ± 0.03	0.21 ± 0.01	0.65 ± 0.04	0.13 ± 0.02	0.02 ± 0.003	-	0.63 ± 0.09	5.67
Arabica	-	-	-	-	-	33.98 ± 0.47	1.89 ± 0.03	5.11
Robusta	-	-	-	-	-	31.22 ± 0.81	2.14 ± 0.05	5.47

EGCG: epigallocatechin gallate, EGC: epigallocatechin, EC: epicatechin, ECG: epicatechin gallate. [a]GP: Twinings Gunpowder; [b]PS: Pure Sencha; [c]EB: English Breakfast; [d]EG: Earl Grey.

Table 3. Color differences in specimens after 72 cumulative h of immersion in various beverages.

Beverage	1 h ΔE_{00}	3 h ΔE_{00}	9 h ΔE_{00}	24 h ΔE_{00}	48 h ΔE_{00}	72 h ΔE_{00}
Green tea (GP)[a]	1.05 ± 0.64	1.57 ± 0.76	2.67 ± 0.94	4.38 ± 1.47	7.38 ± 2.97	10.64 ± 4.23
Green tea (PS)[b]	1.49 ± 1.04	1.77 ± 1.06	2.82 ± 1.67	5.04 ± 2.03	8.63 ± 2.76	11.27 ± 2.82
Black tea (EB)[c]	2.38 ± 1.13	3.98 ± 1.51	6.31 ± 1.68	9.86 ± 2.14	13.50 ± 2.55	15.73 ± 2.99
Black tea (EG)[d]	2.10 ± 0.71	3.16 ± 0.95	5.11 ± 1.42	7.34 ± 2.85	9.97 ± 3.44	12.25 ± 4.13
Arabica	1.55 ± 0.93	2.34 ± 1.02	5.47 ± 2.32	8.74 ± 4.43	11.15 ± 5.75	12.31 ± 4.24
Robusta	1.14 ± 0.43	3.79 ± 1.01	4.88 ± 2.24	8.17 ± 3.32	10.77 ± 4.35	11.07 ± 3.29

ΔE_{00}: color differences. [a]GP: Twinings Gunpowder; [b]PS: Pure Sencha; [c]EB: English Breakfast; [d]EG: Earl Grey.

by absorbance and visual characteristics. To our knowledge, the discoloration of tooth enamel by green tea has not been examined previously using spectrophotometry. However, slight changes in color in restorative materials were observed after 14 days of immersion in green tea, indicating its staining potential (Akay *et al.,* 2018). Atomic force microscopy and scanning electron microscopy analyses done by Manno *et al.* (2020) revealed that green tea exposure caused extrinsic matter to adhere to teeth, which was consistent with the observed discoloration in this study. Although the study conducted by Manno *et al.* (2020) highlighted the enamel-protective properties of green tea through coating elements, it also suggested a potential of staining substances to adhere to enamel surface.

Differences among green tea types were minimal, with both GP and PS showing comparable levels of catechins and similar effects on tooth discoloration. EGCG, the most prevalent catechin in green tea, was found in high concentrations in both varieties, with slightly higher levels in GP green tea. A prior study on EGCG established that interactions between EGCG and flavanols caused color changes, and heat treatment speeds up EGCG oxidation, resulting in browning (Dai *et al.,* 2017). This indicates that catechins, particularly EGCG, could stain tooth enamel.

Although both GP and PS originate from the same plant, that is, *Camellia sinensis*, they differ in origin and processing methods. GP tea, originating from China, involves pan-frying the leaves before rolling them into small balls (Meyer *et al.*, 2023). PS, a type of Japanese tea, is primarily produced by steaming the leaves after they are harvested (Qin *et al.,* 2022). Despite these differences, both types had similar total catechin levels and effects on tooth discoloration.

One of the key findings of this study is the effect of theaflavins on tooth discoloration. Theaflavins give black tea its yellowish-brown color (Chaturvedula and Prakash, 2011). Despite the low levels of theaflavins in black tea, tooth specimens showed significant discoloration upon exposure to these compounds. The multiple regression analysis confirmed a strong positive relationship between theaflavins and ΔE_{00}, indicating their significant staining potential. Among black tea types, EB tea caused greater discoloration than EG tea. The primary distinction between EB and EG tea types lies in the blending of leaves and the inclusion of bergamot oil. EB tea blends leaves from Assam, Sri Lanka, and Kenya, while EG typically uses leaves from a single region and is flavored with bergamot oil (Finsterer, 2002; Sestrimska *et al.,* 2016). EB tea contained more theaflavins than catechins whereas EG tea contained more catechins than theaflavins. This confirms that theaflavins, formed from the oxidation of catechins, are stronger indicators of tooth discoloration, as evidenced by the greater discoloration induced by EB tea. The lesser oxidation of EG, compared to EB tea, raises further questions, necessitating additional research for a comprehensive interpretation.

Theaflavin-induced tooth discoloration is attributed to binding of theaflavins to surface of the enamel, similar to the binding of catechins to tooth enamel. Theaflavins, a type of polyphenols in black tea, bind strongly to proteins, significantly enhancing their staining potential on surfaces (Wu *et al.,* 2020). This was demonstrated by results of the study conducted by Wu *et al.* (2020) that theaflavins can effectively bind with ovalbumin, a major protein in egg white, leading to noticeable pigmentation. Given the protein-rich nature of the pellicle layer on surface of the enamel, theaflavins may bind to proteins within this layer (Yao *et al.,* 2001). This binding may lead to the formation of colored complexes, contributing to the observed discoloration. The affinity of theaflavins for proteins and the porous nature of the enamel may enhance the penetration and adherence of these polyphenols, increasing their teeth staining effect.

Beverage acidity also affects tooth discoloration. Acidic environments erode the enamel, increasing its vulnerability to stains from chromogens (Larnani *et al.,* 2024). Green tea was less acidic than black tea and coffee, potentially contributing to the varying degrees of tooth discoloration observed in this study. Despite its lower acidity, black tea caused more tooth discoloration than coffee, suggesting that factors other than acidity contribute to this effect.

Coffee discoloration is caused by CGAs, melanoidins, and other chromogens. Previous studies have shown that CGAs in coffee strongly indicate tooth discoloration (Kim *et al.*, 2024b, 2024d). Similar to previous findings, Arabica coffee in this study had higher CGA levels, causing greater discoloration of the specimens immersed in it. Since Robusta coffee showed higher absorbance than Arabica coffee, CGA content could be a more significant factor in tooth discoloration than melanoidins. This implies that the discoloration caused by coffee could be more complex than that caused by tea.

The results indicate that further research into the specific chemicals in tea and coffee is necessary to understand fully their tooth staining mechanisms. As previous research indicated that serving temperature variations influenced the discoloration patterns of coffee-induced tooth staining, it is also crucial to examine how these temperature differences affect tea-induced discoloration (Kim *et al.,* 2024d). In coffee, for example, hot variants caused significantly more tooth discoloration than iced ones (Kim *et al.,* 2024d). *In vitro* conditions may not accurately mimic the oral environment, which is influenced by saliva and other factors. Future research should explore how serving temperature, additives, such as sugar and milk, and individual differences in enamel composition and oral hygiene practices affect outcomes. Understanding these factors would help consumers avoid beverage-induced tooth discoloration and improve oral health.

Future studies could also explore the effect of other acidic drinks on tooth enamel surface and discoloration. Children are at risk of tooth staining and dental erosion because of increasing consumption of acidic beverages, such as soft drinks, fruit juices, and other industrialized acidic drinks. These beverages, which are more prevalent in children's diets, significantly affect surface of the enamel, leading to both esthetic concerns and potentially long-term dental health issues (Albarran-Martínez *et al.,* 2023). A study conducted in Saudi Arabia also demonstrated a significant association between the high prevalence of dental erosion in preschool children and the frequent consumption of acidic beverages, such as fruit juices and soft drinks (Al-Dlaigan *et al.,* 2017). Considering the efficacy of low-particle-size toothpastes in removing extrinsic pigmentation, as demonstrated in recent clinical trials, exploring their potential in restoring tea or coffee-stained teeth is important (Butera *et al.,* 2023).

Conclusions

This study revealed several important findings regarding tooth discoloration. Black tea was identified as the most discoloring beverage, with green tea contributing notably to discoloration. The study highlighted theaflavins as significant contributors to this effect. Coffee and green tea also demonstrated similar effects on tooth color. These results emphasized the importance of understanding chemical interactions between beverage components and dental enamel to develop effective strategies for preventing tooth discoloration and promoting oral health.

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Author Contributions

Soyeon Kim contributed to data curation, formal analysis, investigation, methodology, and writing the original draft. Ji Eun Son and Sri Larnani performed formal analysis, validation, review & editing. Hye-Young Sim, Pil-Young Yun, and Young-Jae Kim contributed to formal analysis and review & editing. Young-Seok Park handled conceptualization, funding acquisition, supervision, and review & editing.

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