Effect on tooth discoloration from the coffee drink at various smoke disposal during coffee bean roasting

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Abstract. The Chlorogenic acid compound in a coffee bean can cause external discoloration of the tooth enamel. In general, external tooth discoloration is caused by deposition of a chromogenic agent into the enamel surface of the tooth. To know the tooth discoloration effects of various smoke disposal during coffee bean roasting, 18 tooth specimens were immersed in coffee solutions with varying roasting methods, including without smoke disposal, half-smoke disposal, and full-smoke disposal for 30, 45, or 60 hours. The color alteration was calculated with the CIE L*, a*, and b* formulae using the Vita Easyshade test machine. The results showed that the differences in tooth discoloration (E*) among the solutions were not significant (p > 0.05). The mean E* values ranged from 10.23 to 17.67 and were not clinically significant. In conclusion, variations in the smoke disposal during coffee bean roasting did not affect tooth discoloration.

1. Introduction
Knowledge of the factors affecting tooth discoloration is important for professional dentists and patients who are concerned about the aesthetic factor of the teeth. Therefore, research on tooth discoloration has been the subject of studies for many years [1]. Color changes in the tooth or tooth discoloration can be caused by intrinsic and extrinsic factors. Intrinsic factors relate to the absorption and scattering of color on the tooth enamel and dentin, whereas extrinsic factors relate to the absorption of various materials, such as tea, coffee, and some mouthwashes, into the enamel surface of the tooth [2].

Coffee contains tannin [3] and chlorogenic acid [4] that can cause tooth discoloration. In addition to those substances, a pH of 4.9–5.2 of a coffee solution can aggravate tooth discoloration [5]. In particular, a pH below 5.5 can demineralize the tooth enamel and facilitate deposition of a chromogenic agent into the enamel surface of the tooth [6]. Despite one of the causes of tooth discoloration, coffee is one of the most widely consumed beverages in the world [7]. In fact, the individual daily average consumption of coffee was reported to be 3–4 cups in the United States, 2–3 cups in Canada, and 1–2 cups in Indonesia [7,8]. Currently, there are about 90 types of coffee beans worldwide, but two of the currently best-known types of coffee beans in Indonesia are arabica (Coffea arabica), which originates from the highlands, and robusta (Coffea canephora), which originates from the lowlands. Arabica coffee in Indonesia has a regional characteristic that signifies different tastes; this is known as specialty coffee and comprises Gayo Arabica, Toraja Arabica, Flores Arabica, Bali Arabica, and Papua Arabica [9].
The coffee beans that are traded are dried coffee beans that have been detached from the flesh, horn skin, and epidermis. On the other hand, coffee bean grains are called the green bean, which is derived from the wet coffee fruit and undergoes several levels of processing. After the processing is done and the green coffee beans are obtained, the next stage is roasting. Perfecting the roasting reaction is influenced by two factors: time and temperature. The usual temperature used during roasting is 200 °C–240 °C for 5–30 minutes [10]. The evaporation that occurs during the roasting process causes the coffee beans to lose weight. The evaporation is physically the smoke disposal produced during the roasting process. This stage of smoke production leads to wastage of various substances that affect tooth discoloration, such as chlorogenic acid and tannin [11]. However, most coffee industries pay less attention to the smoke disposal during this roasting process; this may cause redeposition of various substances in the roasting smoke into the coffee beans during the pyrolysis stage. As a result of activated carbon substance reabsorption, causes some substances to be deposited into coffee beans after the roasting process, this is what causes the coffee beans to change color from brown to black after being roasted [12].

Until now, the exact effects of the variations in the smoke disposal of coffee bean roasting on the pH of coffee and the chromogenic agent redeposited into the coffee beans are not yet known. Therefore, this study was conducted to determine the effect of the smoke disposal of coffee bean roasting on the color changes on the tooth enamel surface.

2. Methods
Eighteen tooth specimens were immersed in coffee drinks at various roasting methods, including without smoke disposal, half smoke disposal, and full smoke disposal. Tooth color was assessed using the CIE L*, a*, b* system, as measured by the Vita Easyshade color test kit. The color measurements on the tooth specimens were performed four times: before immersion and after immersion for 30 hours, 45 hours, and 60 hours.

Characterization of the tannin content in the coffee beans was done before roasting. Meanwhile, characterization of the polyphenol content in the coffee beans was done before and after roasting to determine the chlorogenic acid content in the coffee beans. Chlorogenic acid content is proportional to the polyphenol content [13]. The pH of the coffee drinks was measured according to the method of coffee bean roasting, including without smoke disposal, half smoke disposal, and full smoke disposal.

The statistical analysis method that was used in this study was the Shapiro–Wilk test for every change of the tooth since the total number of specimens was less than 50. To test among the smoke disposal of the roasting groups, repeated ANOVA was performed on normally distributed data, and Friedman test with post-hoc Wilcoxon was performed on non-normally distributed data. To test among the immersion times, one-way ANOVA was performed on the normally distributed data, and Kruskal–Wallis test was performed on non-normally distributed data.

3. Results
The tannin level in the coffee beans before roasting was 2.56%. The results of the polyphenol content test and the pH measurement of the coffee beans after roasting with several methods are shown in Table 1.

| Roasting Methods          | Polyphenol content (%) | pH  |
|--------------------------|------------------------|-----|
| Without smoke disposal   | 3.70                   | 4.64|
| Half-smoke disposal       | 3.69                   | 4.72|
| Full-smoke disposal       | 3.61                   | 4.64|
In Table 1, the polyphenol content in the coffee beans was the highest (3.70%) in the roasting method without smoke disposal and the lowest (3.61%) in the roasting method of full-smoke disposal. Therefore, the polyphenol content decreased with the amount of smoke disposal. On the other hand, the pH values of the coffee beans roasted without smoke disposal, and full-smoke disposal was similar and was lower than that in the half-smoke disposal roasting method.

![Graph of Tooth Discoloration (E')](image)

Figure 1 shows that tooth discoloration to dark was not significant (p > 0.05) after immersion in coffee solutions at a roasting method of without smoke disposal for 30, 45, and 60 hours; change in color to dark occurred at 30 hours of immersion time, to light at 45 hours of immersion time, and to dark again at 60 hours of immersion time. In the roasting methods of half-smoke disposal and full-smoke disposal, tooth discoloration to dark was, likewise, not significant (p > 0.05) at all immersion times; however, the change in color to dark increased with increasing immersion time.

Figure 2 shows that the change in brightness of the tooth to dark was not significant (p > 0.05) after immersion in coffee solutions at roasting methods of without smoke disposal, half-smoke disposal, and full-smoke disposal for 30, 45, and 60 hours. In the without smoke disposal group, the change in brightness to dark increased with longer immersion time. In the half-smoke disposal group, the change in brightness to light decreased with longer immersion time. In the full-smoke disposal group, the change in brightness to dark occurred at 30 and 45 hours of immersion time; after that, brightness decreased to light at 60 hours of immersion time.
Figure 2. Graph of the Brightness Changes (L*)

Figure 3. Graph of the Changes in the Reddish-Greenish Degree (a*)

Figure 3 shows non-significant changes from reddish-greenish to reddish (p > 0.05) discoloration of the tooth after immersion in coffee drinks from various roasting methods of without smoke disposal, half-smoke disposal, and full-smoke disposal for 30, 45, and 60 hours. The results of the full-smoke disposal group significantly differed (p < 0.05) from the results of the without smoke disposal group and the half-smoke disposal group; the results of the without smoke disposal group and the half-smoke disposal group were not significantly different (p > 0.05). In the 30 hours of immersion time group, the color increased to reddish and decreased to greenish at 45 hours of immersion time, then returned to reddish at 60 hours of immersion time. On the other hand, in the half-smoke disposal and full-smoke disposal groups, there were nonsignificant changes to reddish (p > 0.05) at 30, 45, and 60 hours; these changes increased with longer immersion time.
Figure 4 shows nonsignificant changes from yellowish-bluish to yellowish (p > 0.05) discoloration of the tooth after immersion in coffee drinks from various roasting methods of without smoke disposal, half smoke disposal, and full smoke disposal for 30, 45, and 60 hours. The color change to yellowish increased with longer immersion time.

4. Discussion
In this study, the absence of significant differences in the color changes (E*) among the roasting methods and among the immersion times was probably because of imperfect pyrolysis process [5]. Pyrolysis includes the browning process and water evaporation of the coffee beans, as well as evaporation of volatile compounds, such as aldehydes, furfural, ketones, and alcohol, that occur during roasting. The method in this research used a roasting time of 20 minutes, which was not sufficient to produce a second cracking sound that signifies breaking of the outer shell of the coffee beans [5]; this absence of a second cracking sound implies incomplete decomposition and redeposition of the chromogenic agents into the coffee beans. The color change values obtained in the overall measurement of the roasting groups were >3.3, which meant that the color change was not clinically significant.

The color changes that occurred may have been caused by the polyphenol and tannin contents in the coffee beans and the low pH levels of the coffee drink. Our results showed that the polyphenol content in the coffee beans after roasting was 3.61% for the without smoke disposal method, 3.69% for the half-smoke disposal method, and 3.7% for the full smoke disposal method. Compared with the half-smoke disposal and the without smoke disposal methods, the full-smoke disposal method had the highest polyphenol content; this was probably due to the lower degree of temperature change in the coffee beans, which led to less polyphenol degradation during the filtration process. The content of red, yellow, and brown pigments in coffee drinks can cause tooth discoloration [5]. Another possible causative factor is tannin, which is a compound that highly reacts with all proteins, including tooth proteins [3]. Based on our results, the 2.56% tannin content in the coffee beans before roasting likely contributed to the color changes. Similarly, Hersek et al. stated that the tooth color changes caused by tea and coffee are caused by tannic acid [3]. The pH level of the three treatment groups in this study was below the critical pH of 5.5 tooth enamel. This result was in line with the results of Gikuru’s research, which stated that at 20 minutes of roasting, the pH level of a coffee drink decreases to achieve a pH of 5.13. The low pH of coffee drinks will cause demineralization of the tooth enamel and deposition of chromogenic agents. This could explain the very high value of color change (E*) obtained in this study.
Color changes in the tooth are caused by changes in the brightness (L'), reddish-greenish degree (a'), and yellowish-bluish degree (b*) along with longer immersion time. In this study, there were no significant differences among the roasting groups and the immersion groups under similar conditions of E', L', and b'. However, in the a' test, there were significant differences among the roasting groups. The absence of significant difference in the L' values among the roasting methods and immersion times was possibly caused by the incomplete decomposition of the polyphenol content in the coffee beans and the absence of redeposition of chromogenic agents on the tooth enamel surfaces. The decrease in brightness to dark was probably caused by the brown pigments in the chlorogenic acid content in the coffee beans [5]. Moreover, the decreasing brightness with longer immersion time was likely due to the larger amount of deposited chromogenic agents with longer specimen immersion time. A low pH value can increase the roughness of the tooth enamel surface and facilitate easier deposition of chromogenic agents. Accumulation of the deposited chromogenic agents caused the decrease in the tooth enamel surface brightness.

The significantly smaller a' change between the full-smoke disposal group and the without smoke disposal group and the half smoke disposal full group was probably due to the larger amount of degraded chromogenic agents that came out during roasting with the full-smoke disposal method. The a' value obtained implied an increase in the reddish degree with a longer immersion time and was probably caused by the red pigment content of chlorogenic acid. The amount of deposited chromogenic agents increased with longer specimen immersion. Also, the increase in the reddish degree could have been caused by a pH value that reached below a critical point and facilitated deposition of the chromogenic agents with red pigments into the tooth enamel surface. Although the change in the reddish-greenish degree was significant in some measurements, it became statistically nonsignificant after being accumulated with change in brightness and yellowish-bluish.

Although the changes in yellowish-bluish degree were not significantly different among the roasting methods, the lowest change was obtained with the full smoke disposal method and 30 hours of immersion, whereas the highest change was obtained with the without smoke disposal method and 60 hours of immersion. The change to yellowish was probably caused by the polyphenol content, which was high at 3.61% for the without smoke disposal method, 3.69% for the half smoke disposal method, and 3.7% for the full smoke disposal method. One of the pigment contents in polyphenols is yellow [5], and the remaining yellow pigment in the coffee bean causes a yellowish change in the tooth, which increases with longer immersion time. This was probably because the amount of deposited chromogenic agents increased with longer specimen immersion. Another possible cause for the change in color was the yellow pigment in the tannin content in the coffee beans [3].

5. Conclusion
Tooth discoloration from drinking coffee was not clinically significant and was not affected by the duration of immersion and the various exiles of smoke during coffee bean roasting.

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