Whitening effectiveness of 10% and 15% carbamide peroxide on extrinsic discoloration by coffee

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Abstract. This study aimed at determining the whitening effectiveness of 10% and 15% carbamide peroxide on extrinsic discoloration by coffee. Thirty-two human premolar teeth were immersed in coffee solution for 8 days to achieve extrinsic discoloration as a base color. A home-bleaching whitening process was performed for 14 days. Color was measured three times: after extrinsic discoloration by coffee, after the application of home bleaching on day 7, and after the application of home bleaching on day 14. The CIE and VITAPAN systems and a VITA Classical Easyshade® spectrophotometer were used to make the color measurements. After extrinsic discoloration by coffee, the results indicated low L* (value), high positive a* (reddish-greenish chroma), and high positive b* (yellowish-bluish chroma). The results after the application using carbamide peroxide home bleaching showed increased L*, decreased a*, and decreased b* relative to before application. Visually, the teeth looked whiter than the normal human tooth color. Both concentrations of carbamide peroxide were effective in whitening teeth showing extrinsic discoloration by coffee. There was no statistically significant difference in the effectiveness of 10% and 15% carbamide peroxide against extrinsic discoloration by coffee when the effectiveness was measured by using the CIE system. However, there was a difference in effectiveness between the two concentrations on day 7 when the effectiveness was measured by using the VITAPAN Classical system.

1. Introduction

A smile showing white, well-aligned teeth is considered by most people to be an attractive feature. However, tooth color varies from white to brownish yellow and darkens with age. Teeth undergo addition of the secondary dentin layer, and extrinsic discoloration and enamel erosion can also affect the dentin color underneath [1]. Tooth discoloration is classified according to the presence of stain. Intrinsic discoloration is the change in color caused by a change in the composition or thickness of the hard tissue of the tooth [1]. Extrinsic discoloration is the change in color that occurs externally from tooth substances on the surface of the tooth or the pellicle [2]. Extrinsic discoloration can be brown, yellow, orange, green, and gray. Extrinsic discoloration agents are present in cigarettes, medicines, and drinks, such as coffee, tea, wine, and soda [1].

Coffee as discoloration agents is related to the polyphenol content [3]. Coffee contains tannin and chlorogenic acid and is a plant from the family Rubiaceae and genus Coffea, which includes various species [4]. At present, coffee is consumed worldwide, including in Indonesia [5]. In 2012, after Brazil and Vietnam, Indonesia was the third largest coffee producer [6]. In 2013, domestic coffee...
consumption in Indonesia reportedly reached 1 kg/capita/year [7]. It explains why many people have suffered from tooth discoloration and why tooth bleaching is common in Indonesia.

Presently, because home bleaching techniques are not time consuming and are safe and effective, they are widely used and accepted as it is successful under the supervision of a dentist [8]. The dental materials commonly used for home bleaching are hydrogen peroxide and carbamide peroxide. Those bleaching agents work by releasing oxygen onto the tooth surface in one reaction called an oxidation–reduction reaction [9]. Since vital tooth bleaching with carbamide peroxide can provide good long-lasting results, it is famous and widely used [10].

The concentration, thickness, duration, and viscosity of carbamide peroxide-containing bleaching materials can affect the degree of whitening [8]. Several manufacturers have introduced carbamide peroxide-containing products at different concentrations to the market, and many of these products make claims about the most effective concentration for whitening. Consequently, dentists must be able to determine the appropriate concentration for each patient. The aim of this study was to evaluate the effectiveness of 10% and 15% carbamide peroxide on whitening of teeth showing extrinsic discoloration caused by coffee.

2. Methods
This was a laboratory experimental study. The research was conducted at the Dental Material Laboratory, Faculty of Dentistry, Universitas Indonesia from August until October 2014. The specimens were 32 human premolar teeth obtained within 1 month after extraction that had been stored in saline solution. This study was approved by the Dental Research Ethics Committee, Faculty of Dentistry, Universitas Indonesia.

The specimens were divided into two groups: the 10% carbamide peroxide group and 15% carbamide peroxide group, each consisting of 16 specimens. The specimens were initially subjected to an extrinsic discoloration process. The specimens were soaked in coffee solution for 8 days. The coffee solution was made by dissolving 1 gr coffee in 10 ml of hot water and was then passed through paper filters and divided into separate 10-ml containers (Figure 1).

![Figure 1. The specimens were soaked in coffee solution in separate 10-ml containers.](image)

Each container was numbered, and one tooth specimen was added with the buccal surface facing the wall of the container. Each coffee solution container was tightly closed for later storage in an incubator for 24 hours. The coffee solution was replaced every day for 8 days. After 8 days, the color of each specimen was measured by using a spectrophotometer (VITA Easyshade®).
The bleaching process was performed by the application of 10% and 15% carbamide peroxide gel to a specimen. Each specimen was placed on top of a portion of microwax and was numbered before bleaching (Figure 2). The carbamide peroxide application process was performed by using a small paintbrush with a gel thickness $P \pm 0.5$ mm, then each specimen was covered with a plastic medicine strip at a distance between the buccal surface and the inside wall of the container of $\pm 0.5$ mm. Next, each specimen was stored inside the incubator for 7 hours. After 7 hours, the specimen was washed with aquades and dried. Specimens that did not receive bleaching gel were stored inside a dry closed container without discoloration agent. The bleaching process was repeated for 14 days.

![Figure 2. The specimen is placed on top of a portion of microwax.](image)

The second color measurement (the first was made after staining) was performed on day 7 of the carbamide peroxide bleaching agent application process. The third color measurement was performed on day 14. The color measurements were made by using a VITA Easyshade® spectrophotometer (Figure 3).

![Figure 3. Placement of the white base and Vita Easyshade® on the top of a work table.](image)

3. Results
To measure the magnitude of the color change ($\Delta E^*$), we first measured value ($L^*$), reddish-greenish chroma ($a^*$), and yellowish-blueish chroma ($b^*$). Table 1 presents the means results for value ($L^*$), reddish-greenish chroma ($a^*$), and yellowish-blueish chroma ($b^*$).
**Table 1.** Mean values of (L*), reddish-greenish chroma (a*), and yellowish-blueish chroma (b*).

| Value (L*)                  | After extrinsic discoloration by coffee | After bleaching application (Day 7) | After bleaching application (Day 14) |
|-----------------------------|----------------------------------------|-------------------------------------|-------------------------------------|
| 10% Carbamide Peroxide      | 74.38                                  | 90.18                               | 92.91                               |
| 15% Carbamide Peroxide      | 75.96                                  | 90.22                               | 93.68                               |
| Reddish-Greenish chroma (a*)|                                        |                                      |                                     |
| 10% Carbamide Peroxide      | 10.70                                  | 2.09                                | 0.73                                |
| 15% Carbamide Peroxide      | 10.69                                  | 1.81                                | 0.36                                |
| Yellowish-Blueish chroma (b*)|                                       |                                      |                                     |
| 10% Carbamide Peroxide      | 39.93                                  | 33.27                               | 29.75                               |
| 15% Carbamide Peroxide      | 41.64                                  | 30.72                               | 28.99                               |

Table 2 presents the color changes (ΔE*) after bleaching application for 7 and 14 days. The Shapiro–Wilk test showed that data from both groups had normal distributions. The t-test was performed to assess the significance of differences in ΔE* between days 7 and 14. There were statistically significant changes in ΔE* values between day 7 and day 14 in both treatment groups.

**Table 2.** Color change (ΔE*) after bleaching for 7 and 14 days.

|                   | Day 7 | Day 14 |
|-------------------|-------|--------|
| 10% Carbamide Peroxide | 20.2  | 24.19  |
| 15% Carbamide Peroxide   | 21.23 | 25.06  |

**Figure 4.** Color change (ΔE*) values at 10% and 15% carbamide peroxide on day 7 and day 14.
As shown in Figure 4, on day 7, the mean color change value was 20.2 after bleaching with 10% carbamide peroxide and was 21.23 after bleaching with 15% carbamide peroxide; however, the difference was not significant by t-test. On day 14, the mean color change value was 24.19 after bleaching with 10% carbamide peroxide and was 25.06 after bleaching with 15% carbamide peroxide; however, the difference was not significant by Independent T-test.

In addition to measuring color changes CIELAB, we used the VITAPAN Classical Shade Guide. The VITA EasyShade® spectrophotometer was used to obtain the Classical Shade Guide data. Table 3 presents the color change measurement data from the 32 coffee-stained specimens before and after bleaching on day 7 and day 14.

Before performing the statistical analysis of VITAPAN Classical Shade Guide data, the color change data had to be assigned a number according to the VITAPAN Classical table shown below:

| Color | B | A | B | D | A | C | C | D | A | D | B | A3,5 | B | C | A | C |
|-------|---|---|---|---|---|---|---|---|---|---|---|-----|---|---|---|---|
| Grade | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12  | 13 | 14 | 15 | 16 |

Table 4 presents the mean color values obtained by using the VITAPAN Classical system.

| After extrinsic discoloration by coffee | After bleaching application Day 7 | After bleaching application Day 14 |
|----------------------------------------|----------------------------------|----------------------------------|
| 10% Carbamide Peroxide                  | 14.2                             | 5.5                              |
| 15% Carbamide Peroxide                  | 13.7                             | 5.5                              |

Table 5 presents the mean color change values by using the VITAPAN Classical system.

| After bleaching application Day 7 | After bleaching application Day 14 |
|----------------------------------|----------------------------------|
| 10% carbamide peroxide           | 5.7                               | 8.7                              |
| 15% carbamide peroxide           | 7.4                               | 8.2                              |

The Mann–Whitney U test showed that there were significant differences in the VITAPAN Classical Shade Guide colors between bleaching with 10% and 15% carbamide peroxide on day 7 but not on day 14.
4. Discussion

In this study, carbamide peroxide was used in gel form at concentrations of 10% and 15% to bleach stained tooth specimens. A previous study showed an effect of 10% and 15% carbamide peroxide on tooth enamel color after 14-day application [11]. However, a difference in the bleaching effectiveness between those two concentrations was not shown. A problem in obtaining reliable data in previous research was that differences in color change values were obtained for different specimens treated similarly, which was caused by differences in the initial base color and use of a conventional measurement instrument, the VITAPAN Classical [11]. Consequently, in the present research, the tooth specimens were all stained with coffee under the same conditions to achieve a similar base color, and the VITA Easypshade spectrophotometer was used.

When using the VITAPAN Classical system, the color after staining with coffee was dark. The dark color was thought to be caused by a polyphenol component, such as tannin, and by chlorogenic acid [3]. The existence of melanoidin, which is brown, because of the Maillard reaction, also was thought to contribute to the dark color of the tooth specimens [12]. Chromogens, such as tannin and melanoidin, can infiltrate and become trapped in the porous tooth enamel. The presence of chlorogenic acid and other acids lowers the pH of coffee. The pH of the coffee solution in this study was 5, which was below the critical pH; tooth enamel below pH 5 undergoes demineralization and can become more porous. Consequently, the color of the tooth specimens in this study became dark after being soaked in coffee for 8 days.

The 10% and 15% concentrations of carbamide peroxide were effective for whitening the coffee-discolored tooth specimens. This finding was demonstrated by home bleaching for 14 days, which gave a brighter color than the mean tooth color obtained in previous research. Cho et al obtained CIE component values of 64.5–83.5 for L*; 1.6–9.8 for a*; and 10.4–29.0 for b* [13]. In the present study, the mean value for L* was 93.9, 0.55 for a*, and 29.3 for b*. The extrinsic discolored tooth specimens were brighter and the reddish chroma value was lower than the tooth color in general. Visually, the tooth looked whiter.

The differences in whitening between the treatment with 10% and 15% carbamide peroxide bleaching were not significant on days 7 and 10. It is thought that this was because both concentrations of carbamide peroxide decomposed to similar levels of hydrogen peroxide. It has been estimated that 10% carbamide peroxide would decompose to 3.35% hydrogen peroxide and that 15% carbamide peroxide would decompose to ±5.17%. Since these concentrations were similar, the free radical ion concentrations produced on hydrogen ionization would also be similar. Therefore, the differences in tooth whitening were not significant.

However, in the test using the VITAPAN classical shade guide system, results different from those of the research of Barnes et al. were obtained [14]. This study showed that the 15% concentration resulted in a brighter color than that of the 10% concentration. The coffee-discolored teeth were 5.7 times brighter after using 10% carbamide peroxide and 7.4 times brighter after using the 15% concentration for 7 days. The difference in results between the two systems was thought to be caused by differences in the sensitivity of the measurements. The VITAPAN Classical system is insufficient for measuring color changes between bleaching treatments [15]. However, on the other hand, the VITAPAN Classical system is a simple method of color measurement that can be easily performed in dental clinics [16]. However, color measurement performed by using the VITAPAN Classical Shade Guide is limited to 16 levels of tooth color, which are arranged by the differences in hue, chroma, and value [15].

In this study, the effectiveness of the two test concentrations for whitening teeth extrinsically discolored by coffee was not significant. Previous study suggested using lower carbamide peroxide concentrations to whiten teeth [17]. In addition, the American Dental Association recommends a concentration of 10% ± 1% carbamide peroxide for bleaching using a tray to achieve the safe and effective bleaching of teeth.
5. Conclusions
Carbamide peroxide home bleaching using 10% and 15% concentrations was effective for whitening teeth; however, the difference in whitening of extrinsically coffee-discolored teeth was not significant.

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