Color space system analysis of tooth enamel whitening with a phenolic extract of strawberry leaf

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Abstract. Teeth discoloration can be treated with dental bleaching but it damages the enamel and gingival tissue. Ellagic acid in strawberry leaf ables to create redox reaction that can whiten teeth. The objective of this study was to determine tooth surface whitening after application with ellagic acid and determine the most appropriate color space system to assess tooth surface color. Strawberry leaf phenolic extract was applied to three teeth with concentration of 15%, 30% and 15% to 30%. Color was analysed using Adobe Photoshop software. Strawberry leaf phenolic extract does not whiten the enamel and the most appropriate color space system is RGB.

1. Introduction
Many abnormalities of the oral cavity have been identified, one of which is discoloration and color changes of the teeth. Indeed, tooth discoloration is a major concern of dentists as it has a high prevalence in society. A study in Chengdu, China found that 48%–49% of the population had experienced tooth discoloration, with 52%–56% of the population reportedly unsatisfied with their tooth color [1]. In the United Kingdom, a study of 3215 subjects reported that half of the subjects had experienced tooth discoloration, with severe discoloration affecting 6% of the population [2]. Tooth discoloration is associated with other oral diseases, including dental caries. Dental caries are closely related to tooth discoloration, particularly in pits and fissures [3]. Tooth discoloration is also related to tooth enamel as discoloration involves the enamel microstructure. Enamel represents the outermost layer of teeth and has a high hardness value due to its content of hydroxyapatite mineral [(HA) Ca_{10}(PO_{4})_{6} (OH)_{2}], which can be as high as 96%. The remainder of enamel is composed of approximately 4% organic substances and water. Microscopically, the structure of enamel consists of enamel rods or enamel prisms [4]. Enamel rods are made continuously from the dentino-enamel junction (DEJ) up to the enamel surface, with an average diameter of 4–6 μm (in the tooth surface area, which is bigger than in the DEJ area) [5].

Bleaching processes to whiten teeth use carbamide peroxide or hydrogen peroxide, which utilizes a redox reaction (reduction-oxidation) that oxidizes the color molecular bond, interrupting the molecular chain of the color pigment. This causes the light reflection of molecules to become brighter because the molecules that reflect light are diminished [6]. However, this bleaching process using chemical materials is damaging in itself to the tooth surface because of its acidic properties. Therefore, it has become desirable to identify herbal or natural ingredients that have similar effects to whiten teeth but without subsequent damage to the tooth surface [7].
Strawberry plants are known to whiten teeth [8]. The secondary metabolite contained in strawberry plants is ellagic acid, which contains H and OH groups that may be used in redox reactions for the bleaching process [9]. In previous studies, extraction of the strawberry leaf consisted of a pure extraction, and a significant difference in tooth discoloration was observed when samples were immersed in a solution containing a 50% concentration of pure strawberry extract [10]. In this study, we used a polar phenol-ethanol extraction using ion materials (H and OH group). In this method, the phenol extraction serves to attract the H and OH groups contained in the strawberry leaf ellagic acid because phenol binds the H⁺ and OH⁻ ions, resulting in an extract with many H and OH groups. These H and OH groups can then be used in redox reactions, which represent the main principle of dental bleaching. By using ellagic acid from strawberry plants, the extract of the strawberry leaf may be used in dental bleaching.

The study of tooth color measurements in Indonesia primarily depends on the human eye, as previously reported by Suwakbur dan Adawiyah [11, 12]. A limitation of using the human eye to determine the color measurement is that the results will be subjective and different for each person. Currently, image processing software packages have tools to assess color, however, each system has its advantages and disadvantages. For example, the RGB and CMY system have different functions [13], and, to date, no study has identified the best system for measuring the color of the enamel surface.

2. Methods

Five samples of tooth were prepared with the following criteria such as free of carious lesions in the buccal surface, no microstructural defects in the buccal surface, no hypoparathyroidism or hypoplasia, no discoloration of any surface and the buccal surface was trimmed using fine sandpaper. Five samples of teeth were spaced using transparent nail polish (5 mm × 5 mm in the buccal surface). Then a tea sample (1.5 grams) was dissolved in 50 mL hot water. The solution was stirred until it was brown and then left until the water temperature changed to room temperature. Four out of five samples were immersed in the tea solution for two weeks. Samples were rinsed with aquades for 5 seconds and then separated based on the treatment. A paperclip was attached to the third, fourth, and fifth tooth in the root apex using double tape or superglue to make the application easier.

The preparation of application materials were done by chopped the dried strawberry leaf using a Philips blender. Then the chopped strawberry leaf was subjected to a phenol extraction using ethanol. The extraction products were stored in a closed container. The extract was diluted with aquades in each bottle of 15% (1) and 30% (2) as much as 20 mL, and then it was labeled and stored at room temperature.

Five samples of tooth were labeled into 1) K+ Tooth, 2) K- Tooth, 3) First Tooth, 4) Second Tooth, 5) Third Tooth. K+ tooth serves as positive control. K- Tooth was immersed in the aquades. The first and second rooth were rinsed using aquades (within 5 seconds) and dried using a chip-blower. Then the teeth were immersed in the extract medium of each concentration (15% and 30%). The application was performed for 7 hours. After 7 hours, the teeth were lifted up using a pinset. Then the teeth were rinsed using aquades (within 5 seconds) and allowed to dry for 10 minutes. Those steps were repeated 28 times for each sample. The third tooth was applied using the same steps but only repeated 14 times for each sample in 15% concentration. After the 14 times repetition, the teeth were immersed in the extract medium with a concentration of 30%. The application was performed for 7 hours. After 7 hours, the tooth was lifted up using a pinset. The teeth were rinsed using aquades (within 5 seconds) and allowed to dry for 10 minutes. Those steps for 30% concentration were repeated 14 times for each sample.

In the application procedure, it was assumed that there was no additional static charge and a shaker was not used. The surface area of the tooth enamel was the same among the samples. The temperature and the amount of the extract of strawberry leaf were also equal, as was the duration of
the application. Thus, we were confident that the surface discoloration observed in each case was caused by the reaction of the strawberry leaf extract to the enamel surface of the tooth.

The tooth surface was captured by a DSLR camera on a tripod. An LED light was placed as the lighting of the camera to prevent the reflection of light into the tooth space. The tooth, in which the color was measured, was positioned using double tape in order to keep it stable, and the buccal surface of the tooth was positioned facing the camera. Photos were taken with these following conditions such as no shadows were present in the buccal surface of the tooth, the setting, distance to the tooth and lighting of the camera were the same for every shot. The camera settings used were as follows: ISO: 200, shutter speed: 1/25 and F: 5.6 After taking the photos, all files were moved onto a computer that had been installed with the Adobe Photoshop image processing application. The tooth color was measured using the color picker tools in the Adobe Photoshop application.

3. Results
This study represents an *in vitro* study with the aims to 1) identify color changes in the tooth enamel surface after the application of a phenolic extract of strawberry leaf and 2) to identify the best color space analysis for the purposes of this study. The experiment was performed by applying the phenolic extract of strawberry leaf for 7 hours 28 times. The first specimen was subjected to a 15% phenolic extract of strawberry leaf, the second was subjected to a 30% phenolic extract of strawberry leaf, and the third was subjected to a 15% phenolic extract for 14 times and a 30% phenolic extract for 14 times. After the application, color changes were analyzed using image processing software with various methods of color space analysis (RGB, Cie Lab, CMY, and HSL).

After data normality was analyzed, it was found that most of the groups had a normal distribution. Therefore, the statistical analysis of descriptive data and one-way ANOVA comparison tests of each element using Cie L*a*b, RGB (Red-Green-Blue), CMY (Cyan-Magenta-Yellow), and HSL (Hue-Saturation, Lightness) color system were performed. For the third specimen, the correlation comparison of the added concentration between each color element was also analyzed.

For the first tooth, the Luminance value decreased by 18.80, the a* component increased by 4.80, and the b* component decreased by 19.40. For the second tooth, the Luminance value decreased by 38.60, the a* increased by 6.00, and the b* component decreased by 18.20. There was a significant difference between the L*, a*, and b* component when analyzed using the L*a*b color space system (Table 1).

**Table 1.** The value of L*a*b* in First Tooth and Second Tooth before and after application of phenolic extract of strawberry leaf in 15% and 30%

|                | L* value | a* value | b* value |
|----------------|----------|----------|----------|
| **Positive Control** | Before: 65.6 | After: 3.8 | Before: 2.8 |
| **Negative Control** | Before: 60.8 | After: 4.0 | Before: 14.8 |
| **First Tooth (15%)** | Before: 74.60 | After: 55.80 | Before: 4.40 | After: 9.20 | Before: 6.60 | After: -12.80 |
| **Second Tooth (30%)** | Before: 75.80 | After: 37.20 | Before: 3.20 | After: 8.20 | Before: 6.00 | After: -12.20 |

**Note:**
The value of L* is in the range 0 to 100, with 0 is black and 100 is white.
The value of a * is in the range -100 to 100, with -100 is green, 0 is gray, and 100 is red.
The value of b * is in the range -100 to 100, with -100 is blue, 0 is gray, and 100 is yellow.
For the first tooth, the Red value decreased by 52.40, the Green value decreased by 51.00 and the Blue value decreased by 14.60. For the second tooth, the decrease in the Red, Green, and Blue values was higher than with a treatment of 15%. The decreased values were 102.40 for the R component, 100.60 for the G component, and 68.00 for the B component (Table 2). By using the RGB color space system for the first and second tooth, a difference in the R and G components was observed. For the B component, there was no significant difference for the first tooth, but the B component was significantly different for the second tooth. In addition, there was a decrease in intensity by 39.33 for the first tooth and 90.34 for the second tooth.

Table 2. The value of RGB in First Tooth and Second Tooth before and after application of phenolic extract of strawberry leaf in 15% and 30%

|                         | R Value |          | G Value |          | B Value |          |
|-------------------------|---------|----------|---------|----------|---------|----------|
|                         | Before  | After    | Before  | After    | Before  | After    |
| Positive Control        | 168     | 157.4    | 155.4   |          |         |          |
| Negative Control        | 160.6   | 143.8    | 120.8   |          |         |          |
| First Tooth (15%)       | 195.60  | 143.20   | 180.80  | 129.80   | 180.80  | 129.80   |
| Second Tooth (30%)      | 196.20  | 93.80    | 184.20  | 83.60    | 184.20  | 83.60    |

Note:
The value of R (Red) is in the range 0 to 240, with 0 is black and 240 is red.
The value of G (Green) is in the range 0 to 240, with 0 is black and 240 is green.
The value of B (Blue) is in the range 0 to 240, with 0 is black and 240 is blue.

For the first tooth, the Cyan value increased by 24.40, the Magenta value increased by 43.60, and the Yellow value decreased by 6.40 after application. For the second tooth, the Cyan value increased by 42.40, the Magenta value increased by 41.80, and the Yellow value increased by 10.20. By using the CMY color space system for the first and second tooth, a significant difference in the C and M components was observed. There was no significant difference for the first and second tooth for the Y component. (Table 3)

Table 3. The value of CMY (Cyan, Magenta, Yellow) in First Tooth and Second Tooth before and after application of phenolic extract of strawberry leaf in 15% and 30%

|                         | C Value |          | M Value |          | Y Value |          |
|-------------------------|---------|----------|---------|----------|---------|----------|
|                         | Before  | After    | Before  | After    | Before  | After    |
| Positive Control        | 34.8    | 34.2     | 33.8    |          |         |          |
| Negative Control        | 36.4    | 38.2     | 53.2    |          |         |          |
| First Tooth (15%)       | 23.20   | 47.60    | 25.80   | 49.40    | 29.60   | 23.20    |
| Second Tooth (30%)      | 23.40   | 65.60    | 24.40   | 66.20    | 28.00   | 38.20    |

Note:
The value of C in the range 0 to 100, with 0 is white and 100 is cyan.
The value of M in the range 0 to 100, with 0 is white and 100 is magenta.
The value of Y in the range 0 to 100, with 0 is white and 100 is yellow.
The Lightness value decreased by 46.17 for the first tooth and 87.17 for the second tooth. For the Saturation component, there was a transformation of the S value of 0.084 for the first tooth and −0.091 for the second tooth. A transformation of the Hue value was also found for the first tooth of 6.21 and for the second tooth of −2.32. By using the HSL color space system for the first and second tooth, a significant difference in the S and L components was observed. There was no significant difference for the first and second tooth for the H component (Table 4).

Table 4. The value of HSL (Hue, Saturation, Lightness) in First Tooth and Second Tooth before and after application of phenolic extract of strawberry leaf in 15% and 30%

|              | H Value |   | S Value |   | L Value |
|--------------|---------|---|---------|---|---------|
|              | Before  | After | Before  | After | Before  | After |
| Positive Control | 94.0    | 0.22 | 158.3   |       |         |       |
| Negative Control    | 23.3    | 0.28 | 135.8   |       |         |       |
| First Tooth (15%)   | 57.18   | 63.40 | 0.23    | 0.31  | 174.50  | 128.33 |
| Second Tooth (30%)  | 60.13   | 57.81 | 0.19    | 0.10  | 180.67  | 93.50  |

Note:
The value of H in the range 0 to 240, with 0 or 240 is red, 40 is yellow, 80 is green, 120 is cyan, 160 is blue, 200 is magenta.
The value of S in the range 0 to 1, with 0 is white and the value 1 is no white content (not black).
The value of L in the range 0 to 240, with 0 is black, 120 is gray and 240 is white.

For the third tooth, the decrease in the L* and b* values occurred after application of the 15% and 30% extracts. With the application of the 15% extract, the L* value decreased by 21.00, the a* value increased by 4.40, and the b* value decreased by 10.80. After that, the application followed with the 30% extract, which resulted in an L* value decrease of 14.60, an a* value increase of 0.80, and a b* value increase of 5.80. By using the L*a*b* color space system for the third tooth, a significant difference in the L* component was observed. No significant difference for the a* and b* components was observed (Table 5).

Table 5. The value of L*a*b in Third Tooth initial, mid and final application of phenolic extract of strawberry leaf in 15% and 30%

|      | L*Value | a* Value | b*Value |
|------|---------|----------|---------|
|      | Initial | Mid      | Final   | Initial | Mid      | Final   |
| Positive Control | 65.6    | 3.8      | 2.8     |
| Negative Control  | 60.8    | 4.0      | 1.8     |
| Third Tooth       | 78.20   | 57.20    | 42.80   | 2.40    | 6.80     | 7.60    | 4.20    | -6.60   | -0.80   |

Note:
The value of L* is in the range 0 to 100, with 0 is black and 100 is white.
The value of a* is in the range -100 to 100, with -100 is green, 0 is gray, and 100 is red.
The value of b* is in the range -100 to 100, with -100 is blue, 0 is gray, and 100 is yellow.
For the third tooth, the RGB value decreased after application of the 15% and 30% extracts. With the application of the 15% extract, the R value decreased by 55.20, the G value decreased by 59.00, and the B value decreased by 38.00. This was followed by the application of the 30% extract, which resulted in a decrease in the RGB value as much as 32.20 (R component), the G component by 36.20, and the B component by 45.40. For the third tooth, there was a decrease in intensity as much as 50.74 after application of the 15% extract and 37.93 after the application of the 30% extract. By using the RGB color space system for the third tooth, a significant difference in the R, G, and B components was observed. Our results indicated that there was a substantial difference in tooth color before and after treatment (Table 6).

**Table 6.** The value of RGB (Red, Green, Blue) in Third Tooth initial, mid and final application of phenolic extract of strawberry leaf in 15% and 30%

|                  | R Value |   | G Value |   | B Value |   |
|------------------|---------|---|---------|---|---------|---|
|                  | Initial | Mid | Final   | Initial | Mid | Final | Initial | Mid | Final |
| Positive Control | 168     |    | 157.4   |    | 155.4   |    |
| Negative Control | 160.6   |    | 143.8   |    | 120.8   |    |
| Third Tooth      | 200.8   | 145.6 | 113.4 | 192.4 | 133.4 | 97.2 | 186.6 | 148.6 | 103.2 |

Note:
The value of R (Red) is in the range 0 to 240, with 0 is black and 240 is red.
The value of G (Green) is in the range 0 to 240, with 0 is black and 240 is green.
The value of B (Blue) is in the range 0 to 240, with 0 is black and 240 is blue.

For the third tooth with application of the 15% extract, the Cyan value increased by 25.00, the Magenta value increased by 25.40, and the Yellow value increased by 7.80. After treatment with the 30% extract, the Cyan value increased by 7.80, the Magenta value increased by 11.80, and the Yellow value increased by 16.80. By using the CMY color space system for the third tooth, a significant difference in the M and Y components was observed. There was no significant difference for the C component (Table 7).

**Table 7.** The value of CMY (Cyan, Magenta, Yellow) in Third Tooth initial, mid and final application of phenolic extract of strawberry leaf in 15% and 30%

|                  | C Value |   | M Value |   | Y Value |   |
|------------------|---------|---|---------|---|---------|---|
|                  | Initial | Mid | Final   | Initial | Mid | Final | Initial | Mid | Final |
| Positive Control | 34.8    |    | 34.2    |    | 33.8    |    |
| Negative Control | 36.4    |    | 38.2    |    | 53.2    |    |
| Third Tooth      | 21.2    | 46.2 | 54.0 | 20.6 | 46.0 | 57.8 | 23.0 | 30.8 | 47.6 |

Note:
The value of C in the range 0 to 100, with 0 is white and 100 is cyan.
The value of M in the range 0 to 100, with 0 is white and 100 is magenta.
The value of Y in the range 0 to 100, with 0 is white and 100 is yellow.
For the third tooth, the Lightness value decreased by 44.33 after application of the 15% extract and the Lightness value decreased by 38.83 after application of the 30% extract. The Saturation component showed a transformation of the S value of −0.0236 after treatment with the 15% extract and −0.0954 after treatment with the 30% extract. A transformation of the Hue value was also found for the third tooth as much as 53.01 after application of the 15% extract and 32.77 after application of the 30% extract. By using the L*a*b* color space system, a significant difference in the L component was observed. There was no significant difference in the H and S components (Table 8).

Table 8. The value of HSL (Hue, Saturation, Lightness) in Third Tooth initial, mid and final application of phenolic extract of strawberry leaf in 15% and 30%

|                  | H Value | S Value | L Value |
|------------------|---------|---------|---------|
|                  | Initial | Mid     | Final   | Initial | Mid   | Final   |
| Positive Control | 94      | 0.22    | 158.3   |
| Negative Control | 23.3    | 0.28    | 135.8   |
| Third Tooth      | 100.2   | 153.2   | 120.4   | 0.17    | 0.15  | 0.05    | 187.8   | 143.5  | 104.7  |

Note:
The value of H (Hue) in the range 0 to 240, with 0 or 240 is red, 40 is yellow, 80 is green, 120 is cyan, 160 is blue, 200 is magenta.
The value of S (Saturation) in the range 0 to 1, with 0 is white and the value 1 is no white content (not black).
The value of L (Lightness) in the range 0 to 240, with 0 is black, 120 is gray and 240 is white.

The correlation test of L*/Luminance for the third tooth showed a very strong negative correlation. In addition, the correlation test of the a component for the third tooth showed a strong positive correlation, whereas that of the b component showed a moderate negative correlation.

Based on the correlation tests for the third tooth, a very strong negative correlation was found for the R, G, and B components, as well as intensity, and a very strong positive correlation was found for the C and M components. In addition, there was a strong positive correlation for the Y component. The correlation test for the Hue component showed a weak positive correlation. For the correlation test of the Saturation and Lightness components, there was a very strong negative correlation.

4. Discussion
Tooth discoloration represents a color change that commonly occurs in teeth. There are numerous materials used to whiten the teeth, varying from those based on chemical to herbal ingredients. The most commonly used teeth whitening material consists of hydrogen peroxide or carbamide peroxide; however, these materials can result in several side effects, including damage to the tooth enamel surface and surrounding tissue [6]. Therefore, herbal ingredients that are able to whiten teeth without damaging the tooth surface or surrounding tissues are highly desirable. The herbal ingredient of strawberry leaf contains ellagic acid, which has been reported to whiten the tooth surface [11].

In this study, an artificial coloring of the tooth samples was first performed by using a tea solution. After that, tooth samples were immersed in a phenolic extract of strawberry leaf with a concentration of 15% or 30%. The first tooth was subjected to a 15% extract concentration, the second tooth was subjected to a 30% extract concentration, and the third tooth was subjected to a 15% extract concentration followed by a 30% extract concentration. This application was performed 28 times for the first and second teeth. For the third tooth, the application was performed 14 times for each
concentration. Color analysis of the teeth was then performed using various color space theory systems.

There were some barriers and difficulties in this study, one of which was the difficulty in finding strawberry leaf in a large amount. To obtain 30 grams of extract, 450 grams of strawberry leaf was needed. Since Strawberry leaf plants only bear fruit if their leaves are lush, sufficient quantity was able to be obtained when it was harvest time. The other barrier was the difficulty in setting up the spectrometer and other equipment to measure the light, as the same distance, lighting, and shutter speed were required for every shoot.

The color analysis we used in this study was based on the RGB, CMY, CIELab, and HSL coloring systems (Figure 1). These systems allowed us to know the location of a color in the RGB, CMY, HSL, and CIELab dimension. The components of these coloring systems were R (Red), G (Green), B (Blue), C (Cyan), M (Magenta), Y (Yellow), I (Intensity), L (Lightness), H (Hue), and C/S (Saturation). Meanwhile, in the CIELab color space theory, the components were L (Luminance), a, and b [13].

The coloring theory of the RGB, CMY, and HSL systems aimed to determine the coordinate of a color in the color space. The L/Lightness value was an axis is the center of the color space, ranging from 0 to 240, with 120 as its median. A higher L value made the color brighter; meanwhile, a lower L value made the color darker [13].

Figure 2 shows the color analysis for positive control group. In this study, the Lightness value before the treatment of the three teeth ranged from 174.5 to 187.83 and the Lightness value after treatment of the three teeth ranged from 93.5 to 128.33. These values indicated that the resulting color was a darker color.

The H/Hue value is a degree to which the color lies. In the RGB system, the H value ranges from 0 to 240 with a color margin of 0–240 as red, 80 as green, and 160 as blue. In the CMY system, an H value of 40 is yellow, 120 is cyan, and 200 is Magenta [13].

The Hue value of the first and second teeth did not change much after the treatment because the H value ranged from 57.1 to 63.3 (between green and yellow); meanwhile, the third tooth showed a transformation of up to 50 degrees (100.16–153.17). The Hue value of 100.16 represented a color between green and Cyan; meanwhile, the Hue value of 153 represented a blue color.

![Figure 1. The RGB (Red-Green-Blue), H-S-L(Hue-Saturation-Lightness), and CIEL*a*b* coloring theory.](image-url)
The color point based on the HSL (Hue-Saturation-Lightness) methods, measured based on RGB (Red-Green-Blue).

**Figure 2.** The color measurement of positive control group using RGB (Red-Green-Blue) Color Space and HSL (Hue-Saturation-Lightness).

The color intensity was influenced by the RGB or CIELab value of a color, and the intensity was influenced by the Lightness value because higher intensity values resulted in higher Lightness values, whereas lower intensity values resulted in lower Lightness values. Based on the results of this study, it was found that the intensity value before treatment ranged from 182.53 to 193.27, whereas the intensity value after treatment ranged from 94.93 to 143.20. These data indicated that the decrease in color intensity affected the Lightness value.

From the results of color analysis, we concluded that the Lightness value had decreased after treatment, which indicated that the color of the teeth had become darker after treatment.

According to the experiment, the tooth surface to which the phenolic extract of strawberry leaf was applied had exhibited a discoloration. However, the discoloration turned out to be a darker color (the RGB value and the Lightness value before and after the application were decreased). This is in contrast to the theory of Suwakbur, (2015) and Adawiyah, (200) [11,12].

The application was done every 7 hours for 28 times based on the usage technique of overnight home bleaching for 1 month (4 weeks in assumption). The concentrations of the phenolic extract of the strawberry leaf used were 15% and 30%, which was done according to the concentration of carbamide peroxide used in home bleaching techniques. The concentration in the home bleaching technique is typically 3%–15% carbamide peroxide. The concentration of 30% is double of the 15% concentration due to the aim of this study, which was to identify the efficacy of the active substances contained in strawberry leaf [14,15].

One of the causes of the tooth discoloration observed was the presence of green pigments in the leaf (chlorophyll), although the leaf had been subjected to a phenolic extraction process (proven by the color of the extraction results, which was dark-greenish black). The color pigment contained in the extract was absorbed into the pores of the enamel rods; therefore, the staining process was getting worse.

The color change after treatment with the 30% extract for the third tooth was not as high as the treatment with the 15% extract because the absorption process of the color pigment in the enamel rods had likely reached its saturation point; therefore, the color change was found insignificant compared with application of the 15% extract.
The phenolic extraction process also eliminated the efficacy of the ellagic acid contained in the strawberry leaf because the extraction process uses heat that damaged the ellagic acid; thus, the ellagic acid was not active to whiten the teeth.

Furthermore, the discoloration of the teeth to a darker color was also caused by a defect in the enamel surface after the treatment, which made the light reflection not fully captured by the camera sensors. Strawberry plants are known to be acidic, and the concentration of the phenolic extraction of the strawberry leaf likely concentrated the acidic substances, which served to damage the tooth surface [16].

In the process of light reflection of a flat surface, light is completely reflected in the same direction. This causes a large amount of light to be absorbed by the camera lens, which makes the color brighter. Generally, the flat surface used in this study was glossy, and with a surface that was not flat (i.e., the tooth), the light was reflected in all directions. This caused the absorption of the light reflection by the camera lens to be not at the maximum, thus making the color darker. The surface that was not flat was matte. Light reflection is known to affect the color visualization of an object [16].

Based on the results of this study, we found that there was a difference in the color value for each color space system. The highest sensitivity value was exhibited for the RGB and HSL color space systems. For example, the $L$ component of the HSL color space system was decreased for every tooth from the control group. The HSL color space system was obtained from the RGB value.

The RGB and CMY color space systems are the most used in terms of tooth coloring. However, both models had different advantages and disadvantages. The CMY color space system is used primarily in the printing process. In this study, the RGB model was more sensitive in analyzing tooth color because RGB has a wider value range compared with the CMY system. This RGB color space was also able to be combined with the HSL color space, thus providing a more accurate analysis. Collectively, our findings indicate that the best color space model for the purposes of this study was the RGB model.

5. Conclusions
The application of a phenolic extract of the strawberry leaf was not able to whiten the enamel surface of teeth in this study. The application of the phenolic extract of the strawberry leaf may damage the tooth surface. There was a sensitivity difference in the tooth surface color measurement for each color space system (CIE L*a*b, RGB, CMY, dan HSL). RGB was the most appropriate color space analysis for assessing the discoloration of the tooth surface.

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