The Influence of Temperature to Change Email Color after Application of Black Tea (*Camellia sinensis L.)*

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Abstract

Extrinsic discoloration can be caused by tea. Drinking tea became a tradition and black tea is often consumed with difference concentration, frequency, and temperature. The study was conducted to determine the effect of concentration, frequency, and temperature of the black tea solution to discoloration of tooth enamel. 17 teeth divided into the positive control group, negative control, a concentration of 1%, 2% and 3%, frequency 60 and 180 times, and the temperature of 30^o, 37^o and 45^o.

The color change was analyzed by photometer and CMY. There is discoloration of the enamel becomes darker (r^2=0.472; p<0.05).

Increased concentration, frequency, and temperature of the tea followed by an increase in dark colors on the enamel.

Clinical article (J Int Dent Med Res 2018; 11(3): 988-993)

Keywords: Discoloration, enamel, tea.

Received date: 12 July 2018 **Accept date:** 25 August 2018

Introduction

Discoloration of the teeth called the discoloration, which is divided into two intrinsic and extrinsic discolorations. Intrinsic discoloration is a stain contained in the enamel and dentin due to the accumulation of materials such as stain tetracycline.[1] Intrinsic discoloration occurs because of changes in the structure, composition, and thickness of the hard tooth tissue. Systemic metabolic diseases and influence the development of teeth and can cause discoloration.[2] Extrinsic discoloration is the change of the enamel that is localized and found on the outer surface of the tooth.[1] Extrinsic discoloration can be caused by the accumulation of the pellicle which resulting stain. Extrinsic discoloration can be brown, black, orange, black, metal, yellow, brown-yellow, golden brown, purple-black, and red-black. Extrinsic discoloration can be caused by the consumption of beverages such as soft drinks, coffee, or tea.[3]

Tea is the most consumed beverage in the world because it has a lot of benefits of antioxidants, anti-inflammatory.[4-6] Consumption of tea in the world is increasing every year.[4] Tea contains chemical compounds in the leaves. These compounds include the phenol group, the non-phenol group, aromatic groups, and the enzyme groups. Tannin/ catechin content in phenols can influence the occurrence of extrinsic discoloration. Tannins cause tooth color changed to brown. Therefore, tea is included in the brown staining group. This is because a lower pH triggers the staining on the teeth.[7-9]

The belief that tea has health benefits makes people constantly consume tea. Sometimes, people are drink tea at high temperatures.[8] Meanwhile, there is a suspected connection between the temperature at which the tea is drunk and the occurrence of tooth discoloration. However, it is unclear from the literature whether there is any association between tea consumption at high temperatures and the occurrence of tooth discoloration. Therefore, it is necessary to conduct further research in order to provide more information to the public regarding the effect of temperature on the discoloration of tooth enamel.

Materials and methods

This research was a laboratory research which aims to determine the effect of various levels of temperature to changes in the color of

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enamel or tooth discoloration that occurs on the surface of the enamel after the application of a solution of black tea (*Camellia sinesis L*). The color change was known to use image processing software Adobe Photoshop and SPSS data processing software. This research was conducted with a total sample of 17 teeth.

In this study there was one tooth that was not given any treatment for the positive control, one tooth that was given treatment in the form of applications in distilled water for the negative control, the concentration group with different levels of concentration of 1%, 2%, and 3% with a frequency of 2 teeth each concentration and frequency of 60 times and 180 times, and the temperature groups with different levels of temperature 30^o, 37^o and 45^o as many as three teeth for each temperature.

Before applied the subject to the solution of black tea, all the teeth surface included the experiment group smoothed using sandpaper CC-1000 and CC-1500 to cut the enamel rods and eliminate the shiny surface on the surface of the tooth. Tooth surface was made a window measuring 5m x 5 mm while other surface covered white nail polish. Before dental solution was applied to black tea, an advance established standard photo was taken.

The teeth were applied to the black tea solution with variable concentrations of 1%, 2%, and 3% and frequencies of 60 times and 180 times. After the application, an analysis was taken to get the result in which concentration and frequency the discoloration of the teeth was appeared. The selected concentration of the best frequencies then used for the next variable at three different temperature levels, including the temperature of 30^{o}C, 37^{o}C, and 45^{o}C. After application of the solution of black tea, an advance established standard photo was taken.

The images were analyzed using image processing software (Adobe Photoshop) to get the CMYK color values. This value was processed using a data processing software (SPSS). Then, a comparison between the images prior to the application on the black tea solution and after application of the solution of black tea to get the color values was analyzed. CMYK color values which will serve as the data groups and test for normality using the Kolmogorov-Smirnov test and homogeneity test to be aware that most of the data group had a normal distribution (p>0.05) and data homogeneous (p>0.05). After testing, we could do different test One-Way ANOVA and Pearson Correlation Test Bivariat. Based on the test results conducted on the treatment of the first phase will be obtained reference concentration and the best frequency selected for the experiment the next stage is to use a variable temperature at three different temperature levels. The system analyzes the color used remains the same, namely CMYK (Cyan-Magenta-Yellow and Black).

Results

	Before	1%	2%	3%
K Value	24,6	28,3	39,6	44
SD*	11,31	10,18	9,34	6,44

Table 1. The mean value of K at concentrations of 1%, 2%, and 3%. **SD = standard deviation*

According to the table 1 above, the average value of K prior to application of a solution of black tea showed a value of 24.6 (with standard deviation of 11.31). There are changes in the average K value before application and after application of a solution of black tea, which is the average value of K at a concentration of 1% 28.3 (with standard deviation of 10.18). This showed that there were significant differences between the average value K prior to the application and the average value of K at a concentration of 1%. Change the color of enamel after application of black tea solution with a concentration of 1% to be darker. The average value of K at a concentration of 2% was 39.6 (with a standard deviation of 9.34). This value was greater than the average value of K at a concentration of 1%. Therefore, discoloration of the enamel at a concentration of 2% was darker than a 1% concentration. The average value K at a concentration of 3% was 44 (with a standard deviation of 6.44). The average value of the K was greatest among other concentration. This showed that the concentration of 3% solution of black tea provides a darker color changes in the concentration of 1% and a 2% concentration.

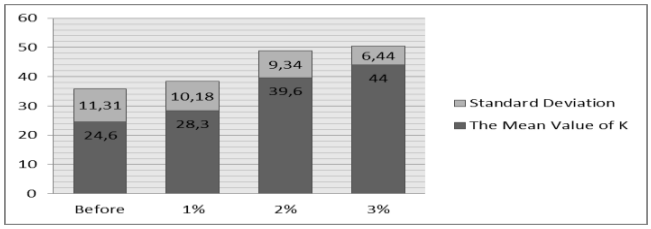

Figure 1. The comparison of average value K at concentrations of 1%, 2%, 3%.

Based on the graph shown in the diagram above (Figure 1), there was a relationship between the average value of K and the increasing of concentration. Graphic chart of the average value of K increases as the increase in the concentration of the tea solution. The higher the concentration of tea is, the greater the average value of K. This was evidenced by the Pearson correlation test between the average value K and concentration, showed a positive correlation value by 0,615. Positive correlation value indicates the higher the concentration, the greater the value of K. The mean value proves that the correlation between the average value of K and the concentration is strong enough and significant.

	Before	60 times	180 times
The Value of K	24,6	35,4	39,1
SD*	11,31	11,72	9,93

Table 2. The mean value of K at the frequency of 60 times and 180 times. **SD = standard deviation*

According to the table 2 above, the average value of K prior to application of a solution of black tea showed a value of 24.6 (with standard deviation of 11.31). There were changes in the average K value before application and after application of a solution of black tea, which is the average value of K at a frequency of 60 times at 35.4 (with a standard deviation of 9.93). This showed that there are significant differences between the average value K prior to the application and the average value of K at a frequency of 60 times. Change the color of enamel after application of black tea solution with a frequency of 60 times become darker. The average value K at a frequency of 180 times was 39.1 (with a standard deviation of 9.93). This value is greater than the average value of K at a frequency of 60 times by a margin of 0.37. Therefore, discoloration of the enamel at a frequency 180 times was darker than the frequency of 60 times. This showed that the frequency of 180 times the black tea solution provides a darker color changes in the frequency of 60 times compare. The frequency value was to be a reference to the application against the black tea solution temperature.

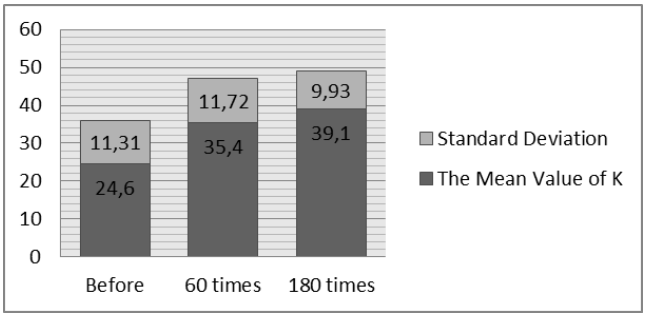

Figure 2. Comparison of the mean value of k at frequencies 60 times and 180 times

Based on the data shown above (Figure 2), there was a correlation between the mean values of K and the increasing of application frequency. The more often the enamel applied to the tea solution, the greater the average value K. High value of K showed that there is a change in color becomes darker email. This is evidenced by Pearson correlation test between the mean values of K and frequency, showing a positive correlation value by 0,498. Positive correlation value indicates the higher the frequency the greater the value K. The value proves that the correlation between the average value of K and the frequency is quite strong and significant.

According to the table 3 below, the average value of K prior to application of a solution of black tea showed a value of 37.1. There were changes in the average K value before application and after application of a solution of black tea, which is the average value of 30° C at a temperature of 64,2. This suggested that there were significant differences between the average value K prior to the application and the value of K at a temperature of 30^o. Change the color of enamel after application of black tea solution with a temperature of 30^o to be darker. The average value K at a temperature of 37^o was 50.5. This value was smaller than the average value of K at a temperature of 30^o. Change the color of enamel at a temperature of 37^o was not darker than the temperature of 30^o. The average value of 45^oC at a temperature was 56.0. The average value of K was greater than the temperature of 37^o but not greater than the temperature of 30^o. Change the color of enamel at a temperature of 45^o was not darker than the temperature of 30^o, but darker than the temperature of 37^o. This suggested that the different levels of temperature showed the average value of K different and give different color change email.

	Before	30°	37°	45°
Value K	37.1	64.2	50.5	56.0
SD*	13,1	9,8	7,0	12,6

Table 3. Comparison of Mean Value of K at Temperatures of 30°, 37° and 45°. **SD = standard deviation*

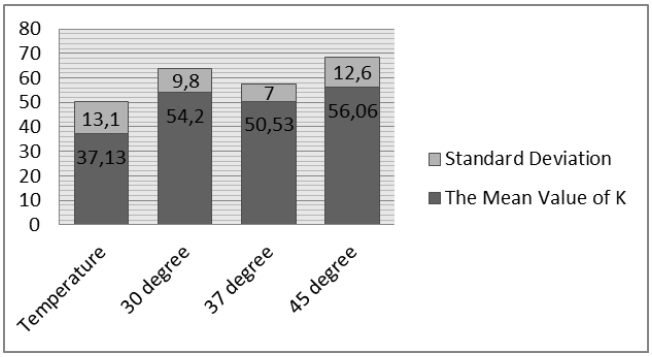

Figure 3. Comparison of Mean Value of K at Temperatures of 30°, 37° and 45°.

Based on the data shown above (Figure 3), there was a correlation between the average value of K and the temperature increasing of the solution. In the diagram showed the average value of K differ significantly at temperatures of 30°C compared to a mean value of the enamel before it was applied to the solution of tea. Meanwhile, the average value of K decreased at 37° but increased at 45°. Different levels of temperature influenced the average value K. This was evidenced by the Pearson correlation test between the average value K and the temperature of the black tea solution showed a positive correlation value of 0.472. Positive correlation value indicates the higher the temperature the greater the average value K. Although the average value of K decreased at a temperature of 37°, the average value of K remained up when the temperature was raised to 45°. The value proves that the correlation between the average value of K and the temperature was quite strong and significant.

Discussion

The habit of Indonesian society in tea consumption is expected to affect a change in the color of enamel. This study aimed to provide information and insight into the people of Indonesia on the effect of temperature levels of black tea solution to tooth discoloration. This study will provide information to the people of Indonesia regarding the influence of the tea solution temperature on tooth discoloration.

The color change can occur as a result of drinking tea because tannin chemical compounds insert into the enamel rods.[10] Crystalline hydroxyl apatite ($CA_{10}(PO_4)_6(OH)_2$), located at the head of the enamel rod, is found parallel to the longitudinal axis of the enamel rods. When further away from the mid-enamel rod, the crystals turn and their position becomes almost perpendicular to the longitudinal axis of the enamel rods. There is a significant difference in that direction of the crystals since there will be an easier substitution of H+ ions. Prior to application of the teeth in black tea solution, the enamel was sanded beforehand to cut the line of the enamel rods. At the time the enamel was applied to the tea solution, compounds contained in the tea reacted with hydroxyl apatite crystals. The hydroxyl apatite crystal unit consisted of thousands of apatite cells arranged in a lattice arrangement. In a hexagonal lattice, Ca ions occupy a hexagonal angle and are opposite the PO_4 ion. The Ca ion is located in the central area of the cell to form a triangular arrangement of two layers.[11]

Phosphate molecules have a larger size than the calcium and hydroxyl ions. Phosphate occupies a dominant place and is illustrated as spheres. Overview hexagonal close-pack and there are empty rooms with the small size of the sphere is one sphere to another. Among these spheres calcium and hydroxyl are contained in the first layer. Then on the second layer, there is half the amount of empty space enclosed by a circle of phosphate on it. In the third sheet, there will be an empty room and open. On the sheet piling, there is the funnel formed between the phosphate spheres. On the funnel are found the remaining calcium ions and hydroxyl ions. Moreover, this hall can trigger other ions with low atomic weight.[11] The decrease in pH in the oral cavity can lead to a sharp increase in apatite solubility. A decrease in the pH of 7-4 units can increase the solubility of apatite up to 7 times. If the pH decreases, the concentration of hydroxyl ions will decrease. This resulting in exciting the proton hydroxyl groups of apatite and the apatite may then break up. The phosphate molecule is closely related to pH levels. When the pH drops, the PO_4 is turned into HPO_2 and then becomes H_2PO_4.[11]

As noted earlier, compounds found in tea can have an effect on the color of enamel. Black tea has a role as an antioxidant that can bind to the minerals iron (Fe), zinc (Zn), calcium (Ca) and proteins.[12] The chemicals contained in black tea that may play a major role in determining the color of the tea are catechins or tannins. The decrease in catechin levels upon enzymatic oxidation results in the brownish color of produced tea leaves.[9] In the state of an alkaline solution, some tannin derivatives can absorb oxygen. One factor that influences the oxidation reaction of one tannin derivative is the temperature. High temperatures can result in electrons being more easily separated and in other molecules more easily capturing electrons.[13] The chemical properties of tannins are soluble in water, and their level of solubility increases as the solution temperature increases. Therefore, when mixing takes place as black tea is brewed with distilled water, the tannin present in black tea becomes dissolved in the water. When tooth enamel is applied to the solution of black tea, the tannins bind to the proteins on the tooth enamel. The presence of an empty hallway between the circular phosphate apatite can draw closely packed tannins to enter and bind with calcium and hydroxyl. At the close-packed apatite, most of the calcium ions and tannins can bind to the mineral calcium. When tannins bind with the calcium ions it influences the condition of the enamel. In addition, the tannins are astringent compounds which are acidic. When tooth enamel is applied to the solution of black tea, the enamel surface becomes exposed to acidic conditions. Lead acid hydroxyl ions on hydroxyl apatite enamel rod down, otherwise it will undergo structural changes with the phosphates changing into phosphoric acid, and the resulting fragmentation of apatite.[11,14]

Various levels of concentrations in black tea consumption are chosen by the Indonesian community. The high K values indicate a dark color on the enamel. This proves that the increased concentrations of black tea can change the color of the enamel which became darker. Based on the research, the black tea solution concentration that led to the most significant changes in the enamel was the 3% solution. Indonesian society has a habit of most people drinking tea at some time during the day. This relates to the lifestyle of each individual. Some people always prefer to drink tea in the morning, while others drink it in the afternoon or evening. Tea is regularly served warm in Indonesian society. The Indonesian Soft Drink Association shows that hot tea had a larger percentage of consumption than other types of beverages. The presentation of tea varies in each community. The selection of a temperature of 30^{o} is assumed to be room temperature, so that the tea is not cold and also not hot. The temperature of 37^{o} is assumed to be mid-temperature, while the temperature of 45^{o} is one at which it is assumed that tea that can still be taken.

This study found a variety of obstacles and challenges. One of these was to keep the current temperature of the applications of black tea solution constant and unchanged at the enamel surface. In addition, the retrieval of data to be processed by the image processing software Adobe Photoshop was not straight forward because of the angle, lighting, distance retrieval and setting for the shutter speed needed to be constant or unchanged.

This research used the CMYK color space for its analysis. The CMYK color model was selected because this study aimed to determine the colour change of enamel toward a darker colour. Based on previous studies, the incorporation of the values of C, M and Y produce black or dark colors. The letter ‘K’ in CMYK represents key or black. Three colors, namely cyan, magenta and yellow, can be combined to absorb all light and produce the final color black. The enamel becoming a darker color was caused by the damaged tooth enamel surface. At the time that light is reflected, the whole light is not fully captured by the camera. Black tea has lower pH levels that are acidic. Acid resulted in demineralized structure in enamel. In the process of the reflectance of light on a flat surface, the incoming light is reflected entirely in the same direction, and so much light is absorbed on the camera lens. This produces a light color. Meanwhile, when the surface is uneven or rough, the incoming light is reflected and scattered in different directions so that the light absorbed by the camera lens is not optimal and produces a dark color.

Conclusions

From the study it can be concluded that increasing the concentration, the temperature will

increase the frequency and change the color to be darker email. Different levels of temperature influence on color change email on concentration and maximum frequency.

Suggestion for this research is to conduct further research using other tea types and kinds of teas from different regions. In addition, the need to inform not to consume tea with high temperatures in order to avoid color changes on the teeth. The results of this study need to be distributed as a source of information for researchers to similar studies may be developed.

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