Effects of Milk, Cheese, and Strawberry Counteracting Tooth Discoloration Induced by Coffee or Red Wine

Selina Yuri Kim

Daegu International School, 22 Palgong-ro 50-gil, Dong-gu, Daegu, South Korea
selinakim1203@gmail.com

ABSTRACT: This study investigated the kinds of foods that counteract teeth discoloration caused by consumption of coffee and red wine. A protein contained in dairy products is known for possessing enamel demineralization properties, and strawberries have been associated with teeth whitening functions. In this study, dairy, and strawberries were examined to determine if they contain properties that can substantially counteract tooth enamel discoloration caused by the consumption of coffee and red wine. When considering discoloration caused by coffee, milk, and strawberries were examined; when considering discoloration caused by red wine, cheese and strawberries were examined. Sixty cow teeth were assigned to ten combination groups and the ΔE* (total color change in Commission Internationale de L'Eclairage (CIE)) was calculated for the color change of teeth after immersion in respective solutions. Dairy products such as milk and cheese reduced discoloration induced by coffee and red wine while strawberry did not. The concentration of beverages was critical to teeth discoloration. Based on our results, we recommend that people consume dairy products such as milk or cheese when they drink coffee or wine. We also recommend people drink light coffee (Americano) or light wine in order to keep teeth whiter and brighter.

KEYWORDS: Dental Hygiene, Tooth discoloration; Cow teeth; Coffee; Wine; Dairy products; Strawberries.

INTRODUCTION

One part of the face people care about most is their teeth. Some of the most common causes of tooth discoloration come from beverages including coffee and wine. These beverages are consumed with high frequency by people with varying lifestyles due to the positive effects that are felt after consumption. The caffeine in coffee increases psychomotor function to stay awake and provides physiological effects by increasing energy.[1] Wine gives relaxation and pleasure to people as well as reduces the risk of cancer, diabetes, gallstones, and cardiovascular disease.[2] However, our teeth become discolored by such beverages, thus, we need to find out the foods which are effective for the prevention of teeth discoloration when taken together with wine and coffee. This paper will look at the kinds of foods that counteract teeth discoloration and make recommendations based on the findings to revise one's diet. The specific research question is as follows: Which foods can prevent teeth discoloration when they are taken together with the stain-inducing beverages?

Coffee and wine are frequently consumed by people, but these drinks are shown to cause tooth discoloration. Coffee contains brown or black colors, and red wine contains red, purple and brown colors.[3] These beverages contain chromogenic polyphenols capable of chemical interaction, and the color of stained teeth is thought to be derived from polyphenolic compounds which provide the color in food.[4] The substances in coffee and wine that are responsible for causing dental stains are known as tannins and are composed of polyphenols such as catechins and leucoanthocyanins. Nathoo[5] explained that these materials generate color due to the presence of conjugated double bonds and are thought to interact with tooth surfaces via an ion exchange mechanism and categorized this discoloration as an N1 type mechanism. The tannins in the pigmented foods react with chromogen which is responsible for colors and result in discoloration by precipitating with chromogenic substances on the enamel of the tooth that is naturally porous. Additionally, the tannins in coffee and wine which are acidic, lower the pH inside a person's mouth and eventually causes discoloration, which is facilitated by a low pH level; acidity causes erosion of tooth surfaces.[6] Moreover, acidity in wine is so strong that it creates rough spots and grooves that enable chemicals that cause staining to penetrate deeper into the tooth.[7] Therefore, frequent intake of wine can lead to the erosion of dental hard tissues and thus, increase the likelihood of tooth discoloration in the presence of pigmented foods and beverages by allowing the penetration of these pigments into the tooth.[6,8]

People commonly drink coffee together with milk and pair-wine with cheese. The milk protein, casein is known to prevent enamel demineralization;[9] more specifically, it stabilizes high levels of amorphous calcium phosphate on tooth surfaces, and thus, prevents demineralization.[10] Therefore, it is pertinent to study whether milk and cheese can counteract teeth discoloration induced by coffee and red wine through protecting enamel surfaces of teeth.

DOI: 10.36838/v2i3.10

Strawberries are also well known for their function to whiten teeth. Strawberries contain a substance known as malic acid, which is effective at dissolving any superficial staining such as chromogenic substances on teeth.[11] Therefore, the tooth-whitening activity of malic acid that is present in straw berries might help diminish discoloration by eliminating some of the stains on the surface of teeth. However, the pigments and dyes in strawberries may deepen discoloration, especially the red dye in strawberries. In addition, the acid of this food may facilitate the discoloration of teeth through the erosion of enamel.[6] Therefore, we need to examine whether strawberries minimize or deepen discoloration of teeth. We also need to investigate a way of combining these dairy products and strawberries with stain-inducing beverages and to determine how they may influence teeth discoloration differently.

In studies of discoloration and whitening of teeth, many re searchers use cow teeth of which the surface closely resembles that of human teeth. These studies examined the staining of enamel with red and white wine;[7] the effect of children's favorite beverages on enamel;[12] the effects of a bleaching agent with calcium;[13] the effect of fluoridated carbamide peroxid on enamel surface change and whitening[14] and the effect of carbonated water on enamel erosion and plaque adhesion.[15] Therefore, cow teeth can be used for the experimentation of discoloration and whitening of human teeth.

RESULTS

Discussion

In order to discover different types of food that would best prevent tooth discoloration, the current experiment was conducted with two cases of stain-inducing beverages:coffee and red wine. For coffee, milk, and strawberry were set as the counteracting beverage and food. For red wine, cheese, and strawberry were the counteracting beverage and food. Those foods were combined with possible causations for counteracting discoloration; for coffee groups, coffee and milk at the same time ('coffee + milk') or milk before coffee ('milk → coffee'), and coffee and strawberry (Str.) at the same time or strawberry before coffee; for red wine groups, the same combination as the coffee groups incorporating cheese instead of milk. A control group was set for coffee groups and another for red wine groups respectively; 'coffee only' groupand 'wine only' group. Thus, five particular groups were set up for the coffee groups and five groups for wine groups, for a total of 10 groups. The change of color was measured after immersing the teeth in different combinations of solution, where the ΔE* means the increase of color change from the pretest scores.

Coffee Groups

The results of coffee groups are presented in Table 1 and Figure 1.

Considering the data resulting from the teeth immersed in each solution for three hours, the teeth groups that were transferred from strawberry to coffee solution (mean 18.58) and the teeth groups that were immersed in the mixture of coffee with strawberry (mean 15.98) resulted in higher color change compared to the control coffee only group (mean 10.87). On the other hand, the teeth groups that milk were set as the counteracting beverage, both the group of transferring from milk to coffee solution (mean 8.50) and the group of mixture of coffee with milk (mean 5.29), resulted in lower color change than the coffee only group. Therefore, in the case of coffee groups, the solutions that contained milk, counteracted discoloration of teeth while the solutions that contained strawberries accelerated discoloration. In addition, the mixture groups (coffee + milk, coffee + strawberry) were lower in their color changes than their respective transferring groups (milk → coffee, strawberry → coffee).

Table 1. The color change of coffee groups (ΔE*).

Solution	N	E^*_0 (pretest) Mean (SD)	ΔE^*_1 (1 hour) Mean (SD)	ΔE^*_2 (2 hours) Mean (SD)	ΔE^*_3 (3 hours) Mean (SD)
Coffee only	6	63.62 (2.49)	3.45 (1.33)	5.98 (1.42)	10.87 (1.29)
Coffee + Milk	6	69.13 (3.48)	2.89 (0.86)	3.99 (1.77)	5.29 (1.79)
Milk → Coffee	6	67.44 (4.93)	4.55 (2.51)	5.74 (1.16)	8.50 (2.34)
Coffee + Str.	6	74.51 (4.56)	6.09 (2.45)	10.48 (4.09)	15.98 (5.27)
Str. → Coffee	6	67.26 (3.98)	6.49 (2.00)	12.41 (2.08)	18.58 (1.80)

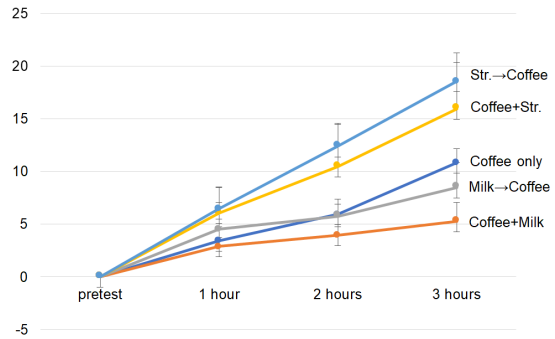

Figure 1. The color change of coffee group (ΔE*).

Red Wine Groups

The results of red wine groups are presented in Table 2 and Figure 2. In the case of wine groups, the teeth that were transferred from strawberry to wine solution (mean 20.59) presented higher color change than the control wine only group (mean 17.27). However, contrasted with the coffee groups, the teeth that were immersed in the mixture of wine with strawberry (mean 10.88) resulted in a smaller mean change than the tooth saturated in the wine only solution. The teeth groups transferring from cheese to wine (mean 15.52) and the group in the mixture of wine with cheese (mean 5.62) also had a lower change in color than the control (wine only) group. This

DOI: 10.36838/v2i3.10

further shows that the solutions containing cheese (cheese → wine, wine + cheese) and the mixture of wine with strawberry reduced teeth discoloration. In addition, the mixture groups (wine + cheese, wine + strawberry) experienced less color change than their respective transferring groups (cheese → wine, strawberry → wine).

Table 2. The color change of wine group (ΔE*).

Solution	N	E^*_0 (pretest) Mean (SD)	ΔE^*_1 (1 hour) Mean (SD)	ΔE^*_2 (2 hours) Mean (SD)	ΔE^*_3 (3 hours) Mean (SD)
Wine only	6	68.74 (6.17)	7.87 (2.40)	13.44 (2.99)	17.27 (3.96)
Wine + Cheese	6	68.49 (5.25)	3.26 (1.11)	4.07 (1.59)	5.62 (1.85)
Cheese → Wine	6	65.06 (3.35)	8.87 (2.49)	10.93 (1.93)	15.52 (2.62)
Wine + Str.	6	65.00 (4.28)	4.15 (1.69)	7.26 (2.25)	10.88 (2.70)
Str. → Wine	6	68.17 (3.45)	9.82 (5.71)	15.77 (4.53)	20.59 (3.77)

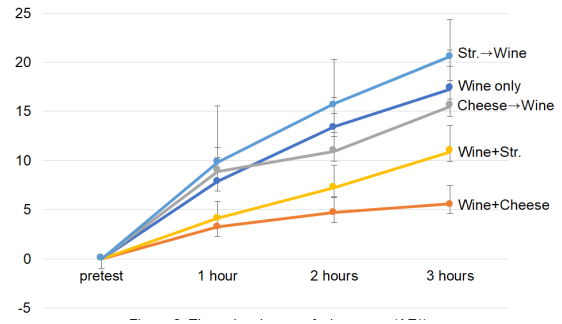

Figure 2. The color change of wine group (ΔE*).

CONCLUSION

Two issues regarding prevention of tooth discoloration are discussed: the effects of dairy products, and concentration of stain-inducing beverages including the issue of both acidity and colorants.

Dairy products such as milk and cheese seem to counteract tooth discoloration induced by coffee and wine. When we refer to the results with less color change among the teeth groups immersed in the mixture of coffee with milk and with cheese, compared with teeth groups in the coffee only or wine only solutions, it is assumed that dairy products such as milk and cheese contain properties that may help reduce discoloration of teeth which were exposed to coffee or wine. Dairy products seem to be able to diminish discoloration as a protein in dairy products protects tooth enamel by stabilizing calcium phosphate on tooth surface.[9,10]

Strawberries did not contribute to diminishing the disco oration of teeth even though they are well-known for their whitening effect by dissolving any superficial staining such as chromogenic substances on the teeth.[11] Rather strawberries facilitated tooth discoloration. This discoloration may be a tributed to the colorants in strawberries and their acidity. In this study, cow teeth were immersed in the mixture of coffee with strawberry or in the mixture of wine with strawberry for three hours. The negative effects of discoloration might be amplified through erosion on the surface of the tooth due to acid, therefore letting the pigments infiltrate deeper into the structure.[6] Therefore, considering the results, the custom of adding milk in different kinds of coffee and having cheese together when drinking wine may be beneficial since dairy products may counteract against discoloring the teeth from the colorants in coffee. However, the opposite might be true for strawberries.

Additionally, the concentration of a stain-inducing beverage might be an element that affects tooth discoloration. Comparing the color changes of the mixture groups with the transferring groups, the color of teeth immersed in the mixture groups of 'coffee + milk', 'coffee + strawberry', 'wine + cheese', and 'wine + strawberry' changed consistently less than the re spective transferring groups ('milk → coffee', 'strawberry → coffee', 'cheese → wine', and 'strawberry → wine'). These results seem to come from the low concentration of colorants; the colorants in coffee and wine are diluted in the mixture groups, and thus the amounts of polyphenolic compounds that are responsible for the coloring of teeth were reduced.[4]

From the experiment with red wine, we can assume that the conce tration of wine is critical to teeth discoloration. The color change of the mixture group of 'wine + strawberry' was less than the transferring group 'cheese → wine' and the wine only group although strawberry contains stain-inducing colorants. It is assumed from this result that the acidity of wine was diluted and further reduced the degree of tooth discoloration when we refer the previous research asserting that the low pH level leads to erosion of dental hard tissues.[6,7,16] More specifically, a low pH causes dissolution of calcified tooth structure, a decrease in enamel hardness and an increase in enamel porosity, and as a result, allows penetration of the pigments of beverages or food into the tooth. Therefore, lowering the concentration of stain-inducing beverages which are acidic is important in order to prevent tooth discoloration.

In conclusion, dairy products such as milk or cheese can minimize the discoloration of teeth induced by coffee or red wine. Another important finding is that the concentration of beverages is critical to teeth discoloration. Therefore, we re commend that people consume dairy products such as milk or cheese when they drink coffee or wine. It will be better if they drink light coffee (or light wine in order to keep teeth minimize the effects of discoloration).

METHODS

Materials

As the physical and chemical characteristics of cow teeth much resemble that of human teeth,[13] 60 cow teeth were used in this study. The extracted cow teeth were obtained from a

butcher and were cleaned and kept in a 0.9% NaCl saline solution. Before the experiment, the parts of cow teeth that were cracked were covered with nail polish in order to prevent the solutions from leaking through. The cow teeth were assigned to 10 groups, with six in each group, in order of the size of the cow teeth, as the thickness of teeth enamel is a critical element to the degree of discoloration.

Materials included 10 capsules of ground coffee bean (Nespresso Ristretto), a bottle of red wine (JINRO house wine of 16.67% alcohol by volume (ABV)), whole milk, cream cheese (Philadelphia), frozen strawberry, 0.9% NaCl saline solution, and a bottle of nail polish. In detail, 40mL of coffee (espresso) was extracted from each capsule of 5.5g; cream cheese was mixed with mineral water in a 1:1 ratio to form a liquid state; and frozen strawberry was ground without any additional water or sweetener. The tool used for measuring color was Minolta CR 400.

Pilot Study

A pilot study was conducted in order to find out how much time was needed for the cow teeth to be discolored and for the researcher to become familiar with the procedure of the experiment and the use of the Minolta CR 400. A tooth was immersed in coffee and another tooth in the mixture of coffee and milk at a ratio of 1:1 for 1 hour. The L*, a*, b* values were measured every 10 minutes. As a result, measuring every hour for three times was determined to be sufficient.

Experimentation for the coffee groups

The cow teeth were immersed in the extracted espresso coffee for the 'coffee only' group and in the coffee and milk mixture - at a ratio of 1:1 - for an hour respectively. For the transferring from milk to coffee ('milk → coffee) group, the cow teeth were immersed in milk for five minutes, rinsed with 0.9% NaCl saline solution, and then immersed in coffee for 20 minutes repeatedly until the time immersed in the coffee solution reached one hour. This procedure was continued so that the teeth to be immersed in each solution for three hours, while measuring the colors each hour. For the experimentation of the 'coffee + strawberry' group and the 'strawberry → coffee' group, the same procedure was conducted as described above.

Experimentation for the red wine groups

Liquid cheese which was made of cream cheese mixed with mineral water was used for the cheese in the transferring from 'cheese → wine' group, and the liquid cheese was mixed with wine at a ratio of 1:1.Except for this cheese condition, all other procedures were the same as described for the coffee groups

Measurement and Analysis

In this study, the colors of the cow teeth were measured with CIE (Commission Internationale de L'Eclairage, CIE) standard wherein the L*, a*, b* refer to the variation in the white-black, red-green and yellow- blue chromaticity respectively.[13] The colors of teeth were assessed four times; pretest, and one hour, two hours and three hours after immersion in the solutions utilizing the Minolta CR 400. Each cow tooth was measured three times for each assessment and the average of L*, a* and b* values was calculated for those color values. Then, the value of the total color change (ΔE*) was calculated using the following formula:

$$\Delta E^* = \sqrt{((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)}$$

ACKNOWLEDGEMENTS

I thank Professor Go from the Department of Chemistry, Soonchunhyang University, for mentoring and giving me advice when I had difficulties. I also thank my mother for pre paring cow teeth, helping with the experimentation, and editing the manuscript..

REFERENCES

(1) Wildman R. E. C.; Richard, S. B. Handbook of Nutraceuticals and Functional Food, 3rd ed.; CRC Press: Boca Raton, FL, 2019, 453-462.

(2) Pramesti, A.; Jasrin,T. A.; Hidayat, O. T. Teeth Re-Whitening Juice on Coffee Stained Teeth. Padjadjaran Journal of Dentistry. 2013, 25(1), 15-20.

(3) Kelleher, M. Dental Bleaching; Quintessence Publishing Co. Ltd: London, 2008.

(4) Watts, A.; Addy, M. Tooth Discoloration and Staining: A Review of the Literature. Br. Dent. J. 2001, 190(6), 309-316. doi:10.1038/sj.bdj.4800959.

(5) Nathoo, S. A. The Chemistry and Mechanisms of Extrinsic and Intrinsic Discoloration. JADA. 1997, 128(April), 6S-10S.

(6) Azer, S. S.; Hague, A. L.; Johnston, W. M. Effect of pH on Tooth Discoloration from Colorant in Vitro. J. Dent. 2010, 38s, e106-e109. doi:10.1016/j.jdent.201.0.07.014.

(7) Dobrescu, C.; Wolff, M. S.; Estafan, D. Staining of the Bovine Enamel with Red and White Wine. Paper presented at International Association for Dental Research (IADR). 2009. Retrieved from: https://iadr.abstractarchives.com/abstract/2009miami-115224/staining-of-the-bovine-enamel-with-redand- white-wine.

(8) Willershausen, B.; Callaway, A.; Azrak, B.; Kloβ, C.; Schulz-Dobrick, B. Prolonged in Vitro Exposure to White Wines Enhances the Erosive Damage on Human Permanent Teeth Compared with Red Wines. Nutrition Research. 2009, 29, 558-567. doi:10.1016/j.nutres.2009.08.004.

(9) Aimutis, W. R. Bioactive Properties of Milk Proteins with Particular Focus on Anticariogenesis. J. Nutr. 2004, 134(4), 989-995.

(10) Ferrazzano, G. F.; Cantile, T.; Quarto, M.; Ingenito, A.; Chianese, L.; Addeo, F. Protective Effect of Yogurt Extract on Dental Enamel Demineralization in Vitro. Aust. Dent. J. 2008, 53(4), 314-319.

(11) Karmawati, I. A.; Yulita, I.; Budiarti, R. The Effect of Strawberry on Color Changing of Tooth with Extrinsic Stain. Paper Presented at the 17th KPPINK Annual Meeting. 2016.

(12) Baek, H. J.; Kang, K. H.; Kim, J. H. An Experimental Study on the Effect of Children's Range Beverage on Bovine Enamel. Journal of the Korea Academia-Industrial Cooperation Society. 2009, 10(9), 2523-2529. (in Korean)

(13) Alexandrino, L.; Gomes, Y.; Alves, E.; Costi, H.; Rogez, H.; Silva, C. Effects of a Bleaching Agent with Calcium on Bovine Enamel. Eur. J. Dent. 2014, 8, 320-325.

(14) Lee, H. J.; Kim, H. D.; Kim, M. Y.; Kwon, T. Y.; Kim, K. H. Effects of Fluoridated 10% Carbamide Peroxide on Enamel Surface Change and Whitening. J. Dent. Hyg. Sci. 2010, 10(2), 95-100. (in Korean)

(15) Lim, D. S.; Ban, Y. H.; Min, Y. E.; Park, J. J.; Yu, Y. J.; In, S. R.; Ju, H. J.; Jung, S. Y.; Hwang, Y. S. The effect of Carbamide Water on Bovine Enamel Erosion and Plaque Adhesion. J. Dent. Hyg. Sci. 2015, 15(4), 437-444. (in Korean)

(16) Al-Dlaigan YH; Shaw L.; Smith A. Dental Erosion in a Group of British 13-year-old School Children. Part : Influence of Dietary Intake. Br. Dent. J. 2001, 190, 258-261.

DOI: 10.36838/v2i3.10

AUTHORS

Selina Yuri Kim, the author of this research, is in her junior year of high school in South Korea. She has always had a passion for science (chemistry, biology and physics) and their applications to human life.