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RESEARCH ARTICLE

Effects of Different Types of Ramen Sauce on Bovine Tooth Discoloration

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Background: This study aimed to determine the effect of ramen sauce on tooth tone changes over time, after selecting three different ramen colors from the ramens sold in the market, and applying the sauce to bovine teeth.

Methods: Healthy bovine teeth were selected, and cutting discs were used to produce 60 specimens (5×5×3 mm), with 15 specimens distributed per county. Three types of ramen (buldak, chacharoni black bean sauce, and ottogi curry noodle) were used as the experimental group, and water was used as the negative control group. Tooth tone measurement was performed using a spectrophotometer (CM-700d) to measure the color before and after 1 (3 h 44 min), 2 (7 h 28 min), 3 (11 h 12 min), and 4 weeks (14 h 56 min). Analysis of the color tone change was performed using Statistical Package for the Social Sciences version 28.

Results: In the experimental group, there was a significant color tone change before and after immersion. L* indicated the largest change in black bean sauce ramen, a* indicated buldak ramen, and b* indicated the largest change in curry ramen. The amount of color change (△E*) was the largest in curry ramen, followed by buldak and black bean sauce ramens. The results of the post-hoc analysis showed significant differences between all groups except buldak and black bean sauce ramens.

Conclusion: All three types of ramen revealed significant color change before and after immersion, and curry ramen showed the largest amount of color change among them.

Key Words: Dental enamel, Tooth, Tooth discoloration

Introduction

1. Background

Oral health refers to a state of oral organization that is not impaired by social life and mental activity, by properly performing the three major functions of the oral cavity. Preservation of healthy teeth is important for maintaining physical, mental, and social health. Oral health is not only related to oral function, but also to various factors such as overall health, sociality, and confidence. In particular, the loss of oral health due to oral diseases can reduce the quality of life felt subjectively[1]. The three major functions of the mouth are chewing, pronunciation, and esthetics, and mouth functions may be lost due to oral diseases such as dental caries and periodontal tissue disease[2]. Moreover, tooth discoloration can damage esthetic functions even if they are not affected by oral disease. Tooth discoloration is divided into exogenous and endogenous discoloration. Exogenous discoloration refers to the change in tooth color due to food and tobacco, whereas endogenous discoloration refers to the change in tooth color caused fetal development, due to genetic factors, saliva components, and tooth surface structure changes caused by tetracycline intake during pregnancy[3]. For this reason, if the esthetic function of the tooth is lost, it can affect an individual's mental and social life. Considering the recent increase in interest and importance of esthetic treatment in dental clinics[4,5], tooth discoloration can have a negative

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effect on oral function.

According to a domestic study dealing with food discoloration, Kim et al.[6] reported that prim coffee, sugar coffee, black coffee, and coffee beans showed tooth discoloration during self-whitening treatment; while Nam and Choi[7] reported that coffee and green tea caused color changes to the whitened teeth when compared with orange juice. Choi et al.[8] reported that as a result of immersing composite resin in five kinds of nectar, including grapes, lemons, oranges, grapefruit, and kiwis, color changes appeared on the surface of the composite resin over time. Kang and Lim[9] reported that soy sauce, red pepper paste, and soybean paste, which are traditional Korean fermented foods, can affect the change in tooth color performed with expert whitening. Jeon et al.[10] reported that red pepper paste and soy sauce caused visible color changes in denture resin when compared with soybean past. In patients who use dentures made of Lucitone199® (Dentsply Sirona Inc., York, PA, USA), which showed the largest color change, it is recommended that they should be careful while eating red pepper paste and soy sauce.

Ramen is a processed food frequently consumed in Korea as a substitute for snacks or meals. It can be easily eaten anytime, anywhere, and people have loved it for a long time because it can be consumed relatively freely at a low price. Ramen evenly records top sales at discount stores, chain supermarkets, and independent supermarkets, as well as convenience stores that are most easily accessible to the general public[11]. As of 2021, Korea has 73 ramen consumption per person, the second highest after Vietnam. By exporting ramen to more than 100 countries worldwide, Korean ramen can be found anywhere in the world; thus, it can be said that Korea is a ramen powerhouse[12]. Despite the continued growth of the ramen market, ramen is still recognized as an unhealthy food. This is because it is a processed food owing to its nature, and high content of fat and sodium per unit, whereas other inorganic substances are low. In a study comparing nutrient intake status and metabolic index based on ramen intake[13], the total calorie, fat, sodium, and vitamin B_2 intake density of the ramen high-intake group were higher than that of the low-intake group, whereas the intake density of carbohydrates, phosphorus, iron, potassium, vitamin A, vitamin B_1, niacin, and vitamin C was lower. In addition, the group with the highest intake of ramen showed a 40% higher prevalence of hyperglycemia and 60% higher risk of abdominal obesity than the group with the lowest intake of ramen. According to the dental caries index calculated by Shin et al.[14], Shin ramen was 12.02 and Jin ramen was 15.83. Even though it is the same soup ramen, the sugar content of Jin ramen is higher, which is similar to that of the chocolate muffin (15.81). Therefore, it can be seen that ramen has a negative effect not only on the health of the whole body but also on the health of the teeth.

2. Purpose

The effects of ramen intake on health, nutrition, and teeth have been researched, but studies on the effects of ramen on tooth discoloration are incomplete. Few studies on ramen have reported tooth discoloration. Therefore, this study aimed to investigate the degree to which teeth are discolored by applying various kinds of ramen sauce to teeth and providing consumers with basic data on the effect of various kinds of ramen on tooth discoloration.

Materials and Methods

1. Ethics statement

This study did not require Institutional Review Board deliberation because it did not involve human and human-derived products.

2. Research materials

The teeth were selected as permanent incisors of cattle with a sound enamel surface. Jeju Samdasoo was selected as a negative control group, and three preferred and different colors (buldak ramen, Samyang Foods, Seoul, Korea; chacharoni black bean sauce ramen, Samyang Foods; and ottogi curry noodle, Ottogi, Pyeongtaek, Korea) were selected as the experimental group (Table 1).

3. Research design

1) Production of specimens

Bovine teeth without caries were selected, and tartar removal and surface polishing were performed using an

Table 1. Experimental Materials

Group	Commercial name	Ingredients	Manufacturer
Experimental group	Buldak ramen	Water, Artificial chicken flavor powder, Soy sauce, Chili pepper powder, Soybean oil, Onion, Red pepper powder, Red pepper seed oil, Yeast powder, Garlic, Modified potato starch, Decolorized chili extract, Paprika extract, Black pepper powder, Curry powder	Samyang Foods, Seoul, Korea
	Chacharoni blackbean sauce ramen	Black bean paste, Water, Onion, Sugars, Soybean oil, Caramel colour (E150c), Artificial beef flavor powder, Onion powder, Textured soy protein powder, Flavour enhancer, Extra virgin olive oil, Modified potato starch, Fructose, Salt	Samyang Foods
	Ottogi curry noodle	Curry powder, Salt, Beef extract powder, Sugar, Onion powder, Glucose, Chicken extra powder, Modified potato starch, Turmeric, Disodium 5- inosinate, Disodium 5- guanylate, Kelp extract powder, Spices(Red pepper, Garlic, Onion, Green onion, Ginger), Tuna extract powder, Black pepper, Hydroluzed vegetable protein, Potato powder, Xantan gum, Malic acid, Chilli extract	Ottogi, Pyeongtaek, Korea
Control group	Jeju samdasoo	Natural mineral water	Kwangdong, Jeju, Korea

ultrasonic scaler and pumice. Bovine teeth, whose surfaces were cleaned, were cut into 5×5×3 mm size using a cutting disc (Ruby cutting discs No. 1; Ruby dental products, Osaka, Japan) to produce 60 specimens; 15 specimens were distributed to each group. The prepared specimens were refrigerated in saline solution until the experiment was conducted.

2) Preparation of experimental group solution

Three types of instant noodles (buldak ramen, chacharoni black bean sauce ramen, and ottogi curry noodle) were used as the experimental group; it was prepared according to the manufacturer's instructions. The experimental and control groups' solutions were set at room temperature for 6 hours to match the same temperature, and then 30 ml was divided into beakers.

3) Application of ramen sauce solution

According to the results of the Kostat survey[15], the average mealtime per meal was set at 32 minutes, and the ramen sauce application time was classified into 1 (3 h 44 min), 2 (7 h 28 min), 3 (11 h 12 min), and 4 weeks (14 h 56 min). Specimens were immersed in the solution at intervals of 1, 2, 3, and 4 weeks to measure the color tone over time. After each time elapse, the specimen was removed from the solution, washed under running water for 1 minute, and dried with a paper towel.

4) Color measurement

The color tone measurement of the specimen was performed using a spectrometer (CM-700d; Konica-Minolta Inc., Tokyo, Japan). Zero adjustment was performed after the sample measurement opening was directed to air, and a white correction was performed by attaching a white correction cap. The immersion was measured repeatedly for 1, 2, 3, and 4 weeks before and after immersion in the ramen sauce, and the average value was calculated after continuous measurement three times per sample. Color values were expressed using CIE L*a*b*, as specified by the International Lighting Commission. L* represents the brightness of the tooth color; a high level means bright, and a low level means dark. a* is the red chroma, (+) indicates the degree of redness, and (−) indicates the degree of greenness. b* is the yellow chroma, (+) indicates the degree of yellow, and (−) indicates the degree of blue. △E* is a value that can quantitatively compare the overall color difference by calculating the three elements in a color difference equation. The amount of color change (△E*) was calculated using the following equation[9]:

$$\triangle E^* = \{(\triangle L^*)^2 + (\triangle a^*)^2 + (\triangle b^*)^2\}^{1/2}$$

5) Statistical analysis

Statistical Package for the Social Sciences version 28.0 (IBM Corp., Armonk, NY, USA) was used for color

measurement. A paired t-test was used to determine the difference in color before and after immersion for each group; repeated measure analysis of variance (ANOVA) was used to determine the color change over time, and one-way ANOVA was used to compare the color change between groups. The post-test was conducted using Tukey's multiple comprehension test and verified with a significance level of 95%.

Results

1. Comparison of bovine tooth colors before and after immersion

On comparing the difference in hue before and after immersion in ramen sauce, brightness (L*), red chroma (a*), and yellow chroma (b*) were significant in all experimental groups except the negative control group ($p<0.05$). As for the L* value, the difference before and after immersion in black bean ramen sauce was the largest at 6.81±0.47, and the difference in the a* value before and after immersion was 4.17±0.51. The difference in the b* value before and after immersion in the curry ramen sauce, showed the largest difference of 11.07±2.13 (Table 2).

2. Changes in brightness over time

Repeated measurement variance analysis to measure the change in brightness of bovine teeth over time revealed that the change in brightness was significant in all experimental groups except for the negative control group ($p<0.05$). Black bean ramen sauce showed the greatest decrease in brightness from 84.34±3.68 before immersion to 77.53±3.21 after 4 weeks. Buldak ramen sauce tended to decrease in brightness from 81.76±2.93 before immersion to 77.32±3.22 after 4 weeks. Curry ramen sauce decreased from

Table 2. Chromaticity Comparison of Bovine Teeth before and after Immersion in Ramen Sauce

Chromaticity	Group (n=15 per group)	Before	After	t	p-value
L*	Water	84.06±2.41	83.67±2.75	0.578	0.573
	Buldak	81.76±2.93	77.32±3.22	8.188	<0.001
	Curry	83.74±3.29	82.17±3.50	5.558	<0.001
	Black bean sauce	84.34±3.68	77.53±3.21	11.235	<0.001
a*	Water	0.60±0.36	0.43±0.65	0.730	0.478
	Buldak	1.50±0.83	5.67±1.34	−25.227	<0.001
	Curry	1.15±0.71	0.15±1.01	10.074	<0.001
	Black bean sauce	1.05±0.77	3.35±0.93	−12.642	<0.001
b*	Water	12.37±1.23	12.08±1.13	0.962	0.352
	Buldak	11.79±1.97	18.12±2.34	−38.922	<0.001
	Curry	11.84±2.73	22.91±4.86	−18.096	<0.001
	Black bean sauce	11.80±0.90	15.56±1.34	−22.309	<0.001

Values are presented as mean±standard deviation.
p-value was determined from paired t-test.

Table 3. Chromaticity L* of Bovine Teeth after Immersion in Ramen Sauce

Group (n=15 per group)	Time (wk)				
	Baseline	1	2	3	4
Water	84.05±2.41	83.25±2.53^{a}	82.93±2.65^{a}	82.50±2.73^{a}	83.67±2.75^{a}
Buldak	81.76±2.93	80.76±2.82^{ab}	78.62±2.73^{b}	77.50±3.01^{c}	77.32±3.22^{b}
Curry	83.74±3.29	80.04±4.16^{b}	80.54±3.75^{ab}	80.83±2.66^{ab}	82.17±3.50^{a}
Black bean sauce	84.34±3.68	80.59±3.08^{ab}	78.04±3.94^{b}	78.11±3.44^{bc}	77.53±3.21^{b}

Values are presented as mean±standard deviation.
$^{a-c}$The same letter indicates no significant difference by post hoc Tukey analysis.
p-values are statistically significance according to stain time by Repeated measures ANOVA ($p<0.05$).

83.74±3.29 before immersion to 80.84±4.16 in the first week and gradually increased in value from the second week to 82.17±3.50 in the fourth week. The changes were significant in black beans, followed by buldak and curry ramen sauce (Table 3).

3. Changes in red chroma over time

Repeated measurement variance analysis to measure the change in red chroma over time revealed that the change in red chroma was significant in all experimental groups ($p < 0.05$). The red color of the buldak ramen sauce increased the most over time from 1.50±0.83 before immersion to 5.67±1.34 after 4 weeks. The redness of the black bean ramen sauce tended to increase gradually from 1.05±0.77 before immersion to 3.35±0.93 after 4 weeks. The curry ramen sauce gradually decreased from 1.15±0.71 before immersion to 0.15±1.01 after 4 weeks. The changes were significant in buldak, followed by black bean and curry ramen sauce. The negative control group showed a significant change over time from 0.60±0.36 before immersion to 0.43±0.65 after immersion; however, the difference before and after immersion was insignificant (Table 4).

4. Changes in yellow chroma over time

Repeated measurement variance analysis to measure the change in yellow chroma of bovine teeth over time revealed that the change in yellow chroma over time was significant in all experimental groups except for the negative control group ($p < 0.05$). The curry ramen sauce increased from 11.84±2.73 before immersion to 22.91±4.86 after 4 weeks, showing the largest increase in yellow chroma over time. The sauce of buldak ramen increased its yellow chroma over time from 11.79±1.97 before immersion to 18.12±2.34 after 4 weeks. The sauce for black bean ramen increased from 11.80±0.90 before immersion to 15.56±1.34 after 4 weeks, similar to curry and buldak. The changes were significant in curry, followed by buldak and black bean ramen sauces (Table 5).

5. Amount of color change after immersion ($\triangle E^*$)

One-way ANOVA used to compare the amount of color change after immersion showed that the difference in color change in each group was significant ($p < 0.05$). As a result of the Tukey test, the difference between the color

Table 4. Chromaticity a* of Bovine Teeth after Immersion in Ramen Sauce

Group (n=15 per group)	Time (wk)				
	Baseline	1	2	3	4
Water	0.60±0.36	0.91±0.51^{b}	0.89±0.55^{b}	1.02±0.51^{c}	0.43±0.65^{c}
Buldak	1.50±0.83	3.01±1.05^{a}	3.44±0.78^{a}	5.18±1.53^{a}	5.67±1.34^{a}
Curry	1.15±0.71	0.95±1.45^{b}	0.32±1.31^{b}	0.14±1.24^{c}	0.15±1.01^{c}
Black bean sauce	1.05±0.77	2.29±0.81^{a}	2.90±1.03^{a}	2.94±0.87^{b}	3.35±0.93^{b}

Values are presented as mean±standard deviation.
$^{a-c}$The same letter indicates no significant difference by post hoc Tukey analysis.
p-values are statistically significance according to stain time by Repeated measures ANOVA ($p < 0.05$).

Table 5. Chromaticity b* of Bovine Teeth after Immersion in Ramen Sauce

Group (n=15 per group)	Time (wk)				
	Baseline	1	2	3	4
Water	12.37±1.23	12.36±1.21^{b}	12.16±1.30^{c}	12.37±1.10^{c}	12.08±1.13^{c}
Buldak	11.79±1.97	14.35±1.97^{b}	15.46±1.66^{b}	17.75±2.29^{b}	18.12±2.34^{b}
Curry	11.84±2.73	18.59±3.17^{a}	21.03±4.13^{a}	23.19±4.78^{a}	22.91±4.86^{a}
Black bean sauce	11.80±0.90	13.95±2.47^{b}	15.23±2.27^{b}	15.35±1.66^{b}	15.56±1.34^{b}

Values are presented as mean±standard deviation.
$^{a-c}$The same letter indicates no significant difference by post hoc Tukey analysis.
p-values are statistically significance according to stain time by Repeated measures ANOVA ($p < 0.05$).

Table 6. Chromaticity △ of Bovine Teeth after Immersion in Ramen Sauce

Group (n=15)	Water	Buldak	Curry	Black bean sauce	p-value
△*	2.63±1.26[c]	9.00±1.05[b]	11.29±2.34[a]	8.30±1.75[b]	＜0.001

Values are presented as mean±standard deviation.
[a-c]The same letter indicates no significant difference by post hoc Tukey analysis.
p-value was determined from one-way ANOVA.

change groups of the buldak and black bean ramen sauce was not significant (p=0.154). Curry ramen sauce had the largest color change at 11.29±2.34, followed by buldak, black bean sauce, and water (Table 6).

Discussion

1. Interpretation

Recently, as people's living standards have improved and social activities have increased, the desire to pursue a happy life have also increased. These changes have also appeared in the field of dentistry. Interest in preventive treatment is gradually increasing compared with treatment-oriented management in the past[16]. Oral health does not simply mean that the oral cavity does not suffer from diseases, but it also means maintaining the condition of teeth and oral tissue organs to live comfortably mentally and socially. This oral health is an essential condition for systemic health[17]. The three main oral functions are chewing, pronunciation, and esthetics. Recently, interest in esthetics has been increasing, such as teeth whitening or receiving orthodontic treatment for a beautiful face[18].

The esthetic function of the oral cavity can be damaged even if it is not affected by oral disease, and tooth discoloration by food is a representative example. Pigment substances in the food permeates into the fine organic space of enamel and penetrate the teeth, eventually changing the color of the teeth[19]. Therefore, to observe the change in tooth color caused by food, this study selected ramen sauce, which is frequently consumed in Korea and can be easily accessed anywhere, and investigated its effect on the color change of the tooth enamel surface.

To calculate an objective measurement value for tooth color, the CIE L*a*b* prescribed by the International Commission on Illumination published in 1976 was used. This color classification system is a color space based on the CIE XYZ defined by the International Commission on Illumination in 1931[20]. The color of the teeth was measured using a spectroscopic colorimeter capable of representing the color of the object with CIE L*a*b*, and the $\triangle E^*$ value was calculated using a color difference equation. The larger the $\triangle E^*$ value, the lower the color stability; the smaller the value, the higher the color stability. A $\triangle E^*$ value less than 1 indicates no visual difference, less than 3.3 indicates clinically acceptable in dentistry, and more than 3.7 indicates a clear difference to the naked eye, which denotes problems in clinical application[21-23].

The L* value, representing the brightness of the tooth color, indicates that the higher the value, the brighter the value, and the lower the value, the darker the tooth color. In this study, the L* value significantly decreased brightness in all experimental groups except for the negative control. The sauce with the largest change in brightness ($\triangle L^*$) was black bean ramen sauce (6.81±0.47), followed by buldak ramen sauce (4.44±0.34). The brightness of bovine teeth immersed in curry ramen sauce (1.57±0.21) was significantly reduced, but the difference before and after immersion was small. In a similar study by Choi et al.[8], the brightness was significantly reduced as a result of applying coffee during the treatment period of self-whitening of natural teeth. However, Lee et al.[24] demonstrated that when artificial teeth were immersed in red pepper paste, soy sauce, and coffee, no significant change in brightness was found. The reason natural and artificial teeth showed different results in brightness changes is purportedly because of the difference in the properties of the material[9].

The a* value refers to red chroma; the closer the value to positive, the more red it is, and the closer it is to negative, the more green it is. In this study, changes in red chroma were significant in all experimental groups, inclu-

ding the negative control group. The sauce with the largest change in red chroma (△a*) was buldak ramen sauce (4.17±0.51), followed by black bean ramen sauce (2.30±0.16). Curry ramen sauce (1.00±0.3) did not show a significant change in red chroma brightness. Bovine teeth immersed in buldak and black bean ramen sauces showed a significant increase in red chroma, whereas bovine teeth immersed in curry ramen sauce showed a gradual decrease in red chroma. The reason the red color of whitening teeth immersed in soy sauce, red pepper paste, and soybean paste showed contradictory results to the results of Kang and Lim[9], which did not show any significant change, is attributed to artificial additives mixed in ramen sauce, a processed food.

b* is a yellow chroma, indicating yellow when the value is closer to positive and blue when the value is closer to negative. In this study, the increase in yellow chroma was significant in all experimental groups except for the negative control group. Curry ramen sauce (11.07±2.13) showed the largest change in yellow chroma (△b*), followed by buldak (6.33±0.37) and black bean ramen sauces (3.76±0.44). The difference between the results of this study and those of Kang and Lim[9] in the red and yellow chroma results are attributed to the artificial additives mixed in ramen sauce, a processed food.

The amount of color change (△E*) before and after immersion, calculated by $\triangle E^*=\{(\triangle L^*)^2+(\triangle a^*)^2+(\triangle b^*)^2\}^{1/2}$ calculation formula, was 3.7 or higher, a level that was not clinically acceptable in all experimental groups except the control group. The sauce for buldak ramen was 9.00±1.05, and the sauce for black bean ramen was 8.30±1.75. Curry ramen sauce showed the largest change in color at 11.29±2.34. Curry ramen sauce did not show much change in brightness and red chroma, but there was a very large change in yellow color. As a result, the color change (△E*) was the largest among all ramen sauces. Choi et al.[5] demonstrated a similar pattern as in this study in that the color change of the composite resin precipitated in curry was the largest as a result of precipitating the composite resin in kimchi soup, red pepper paste, and curry. Therefore, curry ingredients severely color teeth and prosthetics.

2. Limitations

This study could not reproduce the human oral environment because the experiment was conducted with bovine teeth and not human teeth. It was also limited as we could not determine exactly which ingredient caused tooth discoloration among the various artificial additives contained in ramen sauce.

3. Suggestion

The experimental results show that the sauces of black bean, buldak, and curry ramens discolor the teeth. Therefore, consumers are recommended to manage their teeth with proper brushing to prevent food from remaining in the mouth and discoloring their teeth after eating ramen, and if that is not possible, rinse their mouth with water. In addition, as ramens in various colors and tastes are continuously being released, research on whether ramen affects the color of teeth should be conducted in the future.

Notes

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

This article does not require for IRB screening because human origin is not used.

Author contributions

Conceptualization: Ha-Eun Kim, Hyeon-Gyeong Noh, Hye-Min Bae, Hye-Young Lee, and Do-Seon Lim. Data acquisition: Ha-Eun Kim, Hyeon-Gyeong Noh, Hye-Min Bae, and Hye-Young Lee. Formal analysis: Ha-Eun Kim, Hyeon-Gyeong Noh, Hye-Min Bae, Hye-Young Lee, and Do-Seon Lim. Supervision: Do-Seon Lim and Hee-Jung Lim. Writing–original draft: Ha-Eun Kim, Hyeon-Gyeong Noh, Hye-Min Bae and Hye-Young Lee. Writing–review & editing: Do-Seon Lim and Hee-Jung Lim.

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Data availability

The supporting data of this study are available from the corresponding author upon reasonable request.

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