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Paper

Visual Palatability of Food Dishes in Color Appearance, Glossiness and Convexo-concave Perception Depending on Light Source

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ABSTRACT

This study aims to reveal visual factors which determine the visual palatability of food dishes. We conducted subjective experiments under different light sources, and examined the correlation between the visual palatability and the visual factors, color appearance, glossiness, and convexo-concave perception. We prepared twelve kinds of food dishes, and measured the chromaticity values of all dishes under six kinds of light sources. Next, we transformed the measured data into their respective RGB values. This color management process ensures that the digital images can be displayed with the same chromaticity values as the real objects so that participants can observe the same visual stimuli with no olfactory cues. Twenty participants observed one of the images for one minute, and evaluated the "visual palatability", and answered subjectively three factors, "color appearance", "glossiness" and "convexo-concave perception". As a result, it was revealed that higher correlated color temperature light makes the dishes more palatable, suggesting that the color appearance is an important visual factor for the visual palatability of food dishes. In addition, it was shown that the visual palatability of the raw food dishes and the dishes with sauce can be affected by both color appearance and glossiness depending on the light source.

KEYWORDS: visual palatability, color appearance, glossiness, convexo-concave perception

1. Introduction

Appearance of food dishes influences their visual palatability. Visual palatability depends on visual factors, such as color appearance, gloss, luster, the feel of unevenness or the impression of concave and convex (convexo-concave perception). These visual factors are determined by not only the properties of the surface of the food but also by some environmental factors such as the lighting.

Effects of color and light on the appearance or visual palatability of foods have been examined in some previous studies. It was reported that some kinds of food didn't show any remarkable difference between the conventional light source, such as incandescent lamp and fluorescent lamp, and the LED lamp in a subjective experiment on "freshness", "appeal", "natural appearance" and "reliability"[1]. Another study reported that the color rendering evaluations in LED lighting condition were lower than in incandescent light condition, and "fresh" and "bright" evaluation were higher with higher color temperature LED light[2]. Also, we reported that higher illuminance on a dining table gave a more active impression, and that lower color temperature light made diners more comfortable[3]. As for the blue light effect on the appetite, it was reported that the women's appetite for the food illuminated by blue and green light was lower than men's[4]. On the contrary, another study reported that blue lighting decreased the hedonic impression of the food's appearance, but not the willingness to eat, and that the blue lighting significantly decreased the amount consumed in men, but not in women, compared to yellow and white lighting conditions[5]. These reports implied that the lighting effect on the appearance of foods varied depending on which visual factor or evaluation point was focused.

On the other hand, gloss or luster was also an important visual factor for the visual palatability of foods as well as color. In a previous study, the appearance of a fried veal was evaluated in terms of "overall color" and "oily appearance"[6]. It was also reported a measurement method of the gloss of foods using image analysis[7]. Other studies reported that the gloss or luster ('Teri' or 'Tsuya' in Japanese) was the important factor for the palatability of some Japanese foods[8][9]. However, there were little studies about the lighting effect on the gloss or luster of foods.

This study aims to reveal the visual factors which determine the visual palatability of food dishes. We con-

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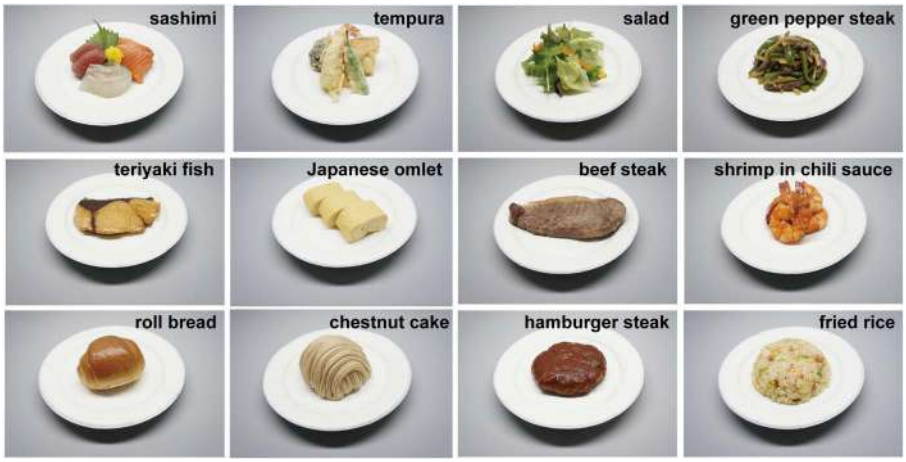

Figure 1 Food dishes as visual target

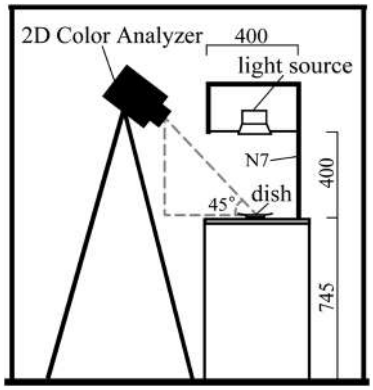

Figure 2 Measurement space

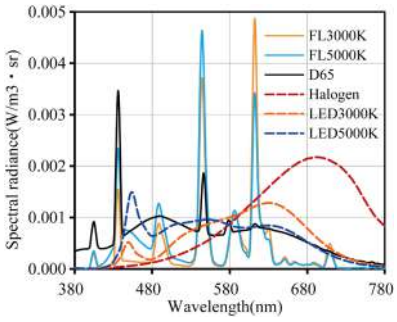

Figure 3 SPD of each light source

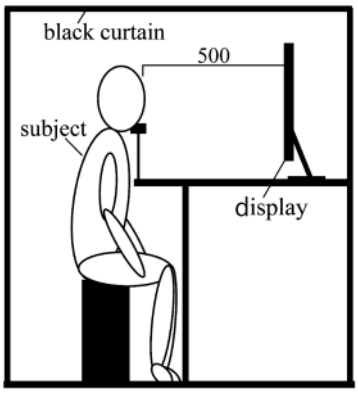

Figure 4 Experiment space

Table 1 Lighting conditions

No.	Light source	Diffusive/directional	CCT (K)	*Ra*
1	fluorescent lamp (3000 K)	diffusive	2977	82
2	fluorescent lamp (5000 K)	diffusive	5177	83
3	fluorescent lamp (D65)	diffusive	6887	94
4	halogen lamp	directional (beam angle 20°)	1885	64
5	LED (3000 K)	directional (beam angle 45°)	2916	87
6	LED (5000 K)	directional (beam angle 45°)	5296	95

Table 2 Luminance and xy-chromaticity values of food dishes

Food dish	*L* (cd/m^2)	*x*	*y*	Food dish	*L* (cd/m^2)	*x*	*y*	Food dish	*L* (cd/m^2)	*x*	*y*
sashimi (tuna)	5.80	0.46	0.47	tempura (shrimp)	18.13	0.41	0.47	shrimp in chili sauce	7.86	0.49	0.46
sashimi (salmon)	9.09	0.47	0.46	tempura (sweet bell pepper)	10.97	0.39	0.47	hamburger steak	4.09	0.45	0.49
sashimi (porgy)	13.67	0.39	0.44	tempura (pumpkin)	17.87	0.42	0.44	beef steak	5.40	0.43	0.50
salad	6.99	0.41	0.52	tempura (shiitake mashuroom)	9.25	0.39	0.46	roll bread	8.66	0.45	0.47
Japanese omlet	22.53	0.42	0.45	green pepper steak (green bell pepper)	4.82	0.39	0.55	chestnut cake	12.30	0.41	0.44
teriyaki fish	8.53	0.46	0.48	green pepper steak (beef)	6.22	0.42	0.51	fried rice	17.70	0.37	0.44

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ducted a subjective experiment under different light sources, and examined the correlation between the visual palatability and the visual factors, color appearance, glossiness, and convexo-concave perception.

2. Methods

First, we prepared twelve kinds of food dishes as shown in Figure 1, sashimi (sliced raw fish), tempura (Japanese fritter), teriyaki fish (yellowtail fish broiled with soy sauce and sweet sake), Japanese omelet, hamburger steak, beef steak, green pepper steak, shrimp in chili sauce, salad, roll bread, fried rice, and chestnut cake (mont blanc aux marrons). These were chosen among those frequently served in Japanese restaurants and households and having in consideration of their characteristics in color appearance, glossiness, and convexo-concave perception.

Secondly, we measured the chromaticity values of all dishes using a two-dimension Color Analyzer (CA-2000, KONICA MINOLTA) under six kinds of light sources in a dark room as shown in Figure 2. Each dish was set in a box with the inside wall N7, and illuminated by one of the six kinds of light sources. Each light source was set 40 cm perpendicularly above the dish, and the illuminance on the dish was 300 lx. Table 1 shows the conditions of the light sources. Figure 3 shows the spectral power distribution of the light sources used in the experiment. Table 2 shows the luminance and xy-chromaticity values of the major points of each food dish under D65.

Thirdly, we transformed the measured data into their respective RGB values using the calibration data of an LCD monitor (CG245W, EIZO) used in this experiment. This color management process ensures that the digital images can be displayed with the same chromaticity values as the real objects so that the participants can observe the same visual stimuli with no olfactory cues. Each image of the dishes was randomly presented on the monitor in the experimental room as shown in Figure 4.

Twenty participants observed one of the images for one minute, and evaluated the "visual palatability", and answered three subjective factors, "color appearance", "glossiness" and "convexo-concave perception", according to a six steps categorical scale, 'very good', 'good', 'barely good', 'barely bad', 'bad' and 'very bad'. They were all female university students, in their twenties. Additionally, a preliminary experiment using the real food dishes was conducted. Three female subjects evaluated the real stimuli under the same conditions as the experiment using the digital images of food dishes. As a result, the differences of both evaluation values were within one step of categorical scale in 91% of the data. Therefore, the evaluation results using digital images

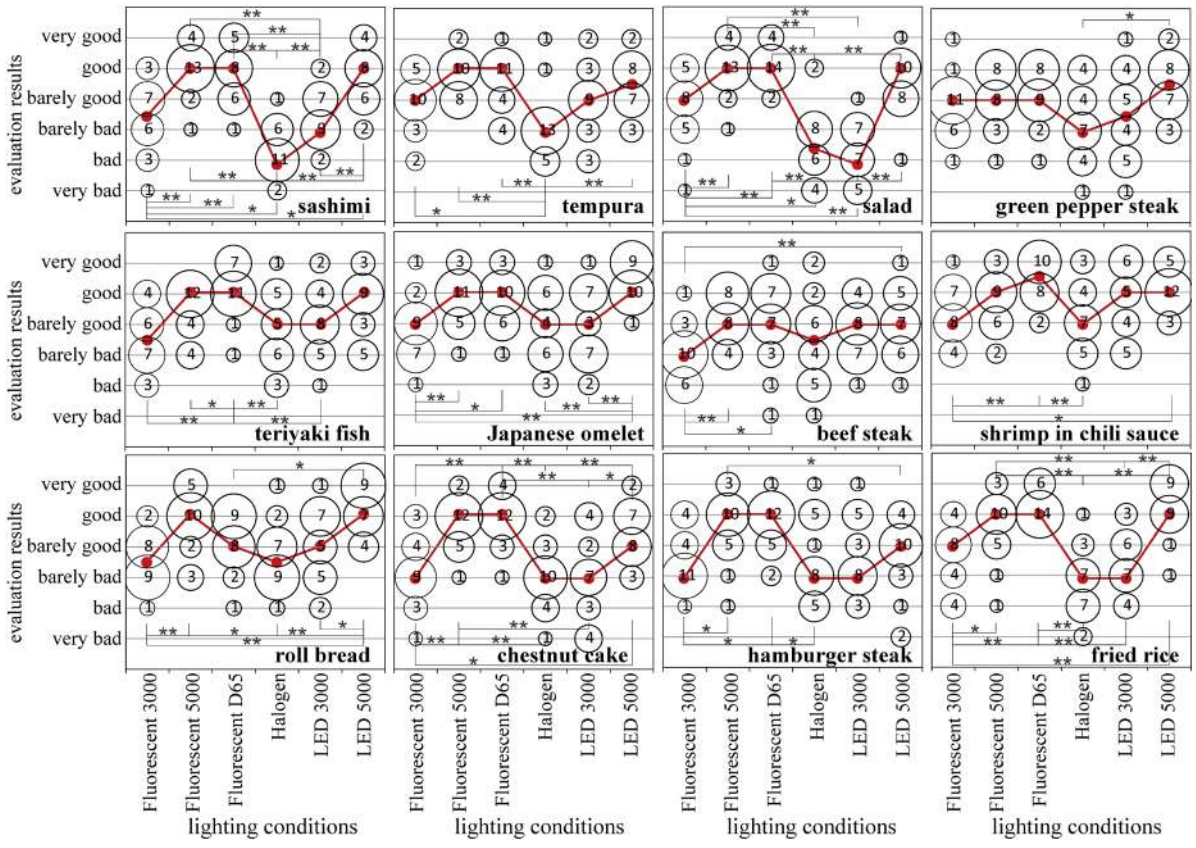

Figure 5 Evaluation results of visual palatability under each lighting condition (*p<0.05, **p<0.01)

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were regarded as similar to those using real foods.

3. Results

The evaluation results acquired in this experiment were shown graphically in the frequency distribution and the median values of the answers. We analyzed the data using Kruskal–Wallis test.

3.1 Evaluation results of visual palatability

Figure 5 illustrates the evaluation results of the visual palatability under each light source. It was revealed that the visual palatability of sashimi, salad, Japanese omelet, fried rice and chestnut cake was higher under the 5000 K fluorescent lamp, the D65 and the 5000 K LED, whereas lower under halogen lamp and 3000 K LED. The visual palatability of the roll bread under 5000 K fluorescent lamp and 5000 K LED was higher, and lower under the 3000 K fluorescent lamp and the halogen lamp. It was also shown that tempura was visually palatable under the D65 and the 5000 K fluorescent lamp but not palatable under the halogen lamp. The palatability of hamburger steak was higher under the 5000 K fluorescent lamp and the D65 than that under the 3000 K fluorescent and the halogen. Teriyaki fish was visually palatable under D65.

The correlations between the evaluation results of the visual palatability and the correlated color temperature (CCT) were examined by calculating Pearson's correlation coefficient (R). We found strong correlations between all dishes except for beef steak and roll bread (R>0.7). These results implied that higher correlated color temperature light can make most of the dishes more palatable.

3.2 Evaluation results of color appearance

Figure 6 illustrates the evaluation results of the color appearance under each light source. It was revealed that the color appearance of most of the dishes, sashimi, tempura, teriyaki fish, Japanese omelet, fried rice, salad, roll bread and chestnut cake, were higher under the 5000 K fluorescent lamp, the D65 and the 5000 K LED, whereas lower under the halogen lamp and the 3000 K LED lamp. It was also cleared that the evaluations of sashimi and salad were higher under the 3000 K fluorescent lamp.

The correlations between the evaluation results of the color appearance and the color rendering index (Ra) were examined by calculating Pearson's correlation coefficient (R). We found strong correlations between them in four kinds of Japanese dishes (sashimi, tempura, Japanese omelet and teriyaki fish), green pepper steak and roll bread (R>0.7) whereas little correlation in Montblanc cake and hamburger steak (R<0.4).

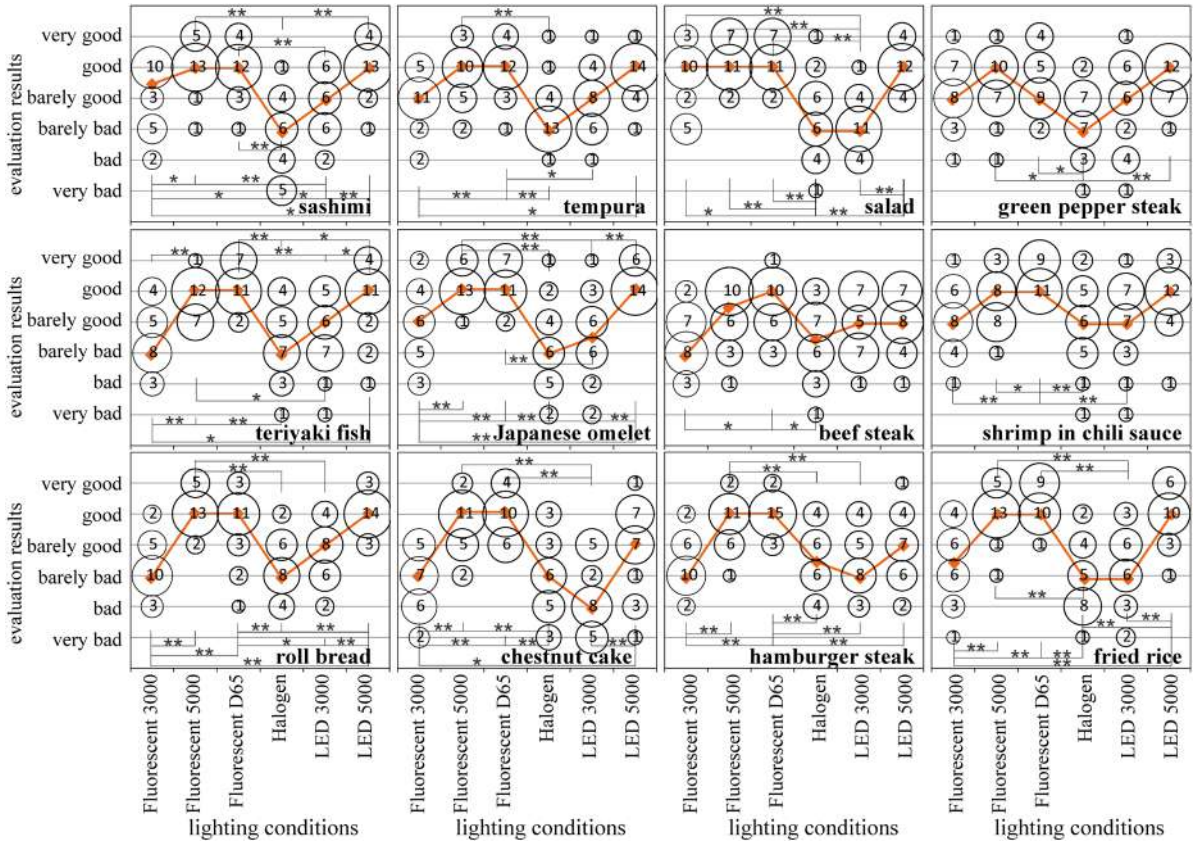

Figure 6 Evaluation results of color appearance under each lighting condition (*p<0.05, **p<0.01)

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3.3 Evaluation results of glossiness

Figure 7 illustrates the evaluation results of the glossiness under each light source. It was revealed that the glossiness under the halogen lamp, the 3000 K and 5000 K LED were higher than that under the D65, 3000 K and 5000 K fluorescent lamp in sashimi, Japanese omelet, fried rice and chestnut cake. It was shown that the glossiness evaluation was higher in teriyaki fish, shrimp in chili sauce, green pepper steak, beef steak and hamburger steak, and that was lower in tempura and salad under any light source. These results indicate that directional light sources make some dishes glossy, suggesting that the surface property of the food is a more influential factor than the lighting condition.

3.4 Evaluation results of convexo-concave perception

Figure 8 illustrates the evaluation results of the convexo-concave perception under each light condition. It was revealed that the convexo-concave perception of sashimi, Japanese omelet and fried rice was higher under the 5000 K LED than that under the 3000 K fluorescent lamp. The evaluation of salad under the 5000 K LED was higher than that under the 3000 K LED but no specific relation was found between the convexo-concave perception and the light source in most dishes.

4. Visual factors related to visual palatability

We analyzed these evaluation results with a multiple regression; "visual palatability" was used as response variable, and "color appearance", "glossiness" and "convexo-concave perception" were used as explanatory variables. Table 3 shows the statistic results of the multiple regression by the standardized partial regression coefficient.

Strong positive correlations were found between "visual palatability" and "color appearance" in all dishes (p<0.001). It was also shown positive correlations between "Visual palatability" and "glossiness" in sashimi, Japanese omelet, hamburger steak, green pepper steak, shrimp in chili sauce and roll bread (p<0.05). These results indicated that color appearance is an important visual factor for the visual palatability of the dishes. It was also revealed that the visual palatability of the raw food dishes and the dishes with sauce were affected by both color appearance and gloss.

5. Conclusions

Above mentioned results of this study are summarized as follows.

(1) Higher correlated color temperature light makes most of the dishes more palatable.

(2) Strong correlations exist between the color appear-

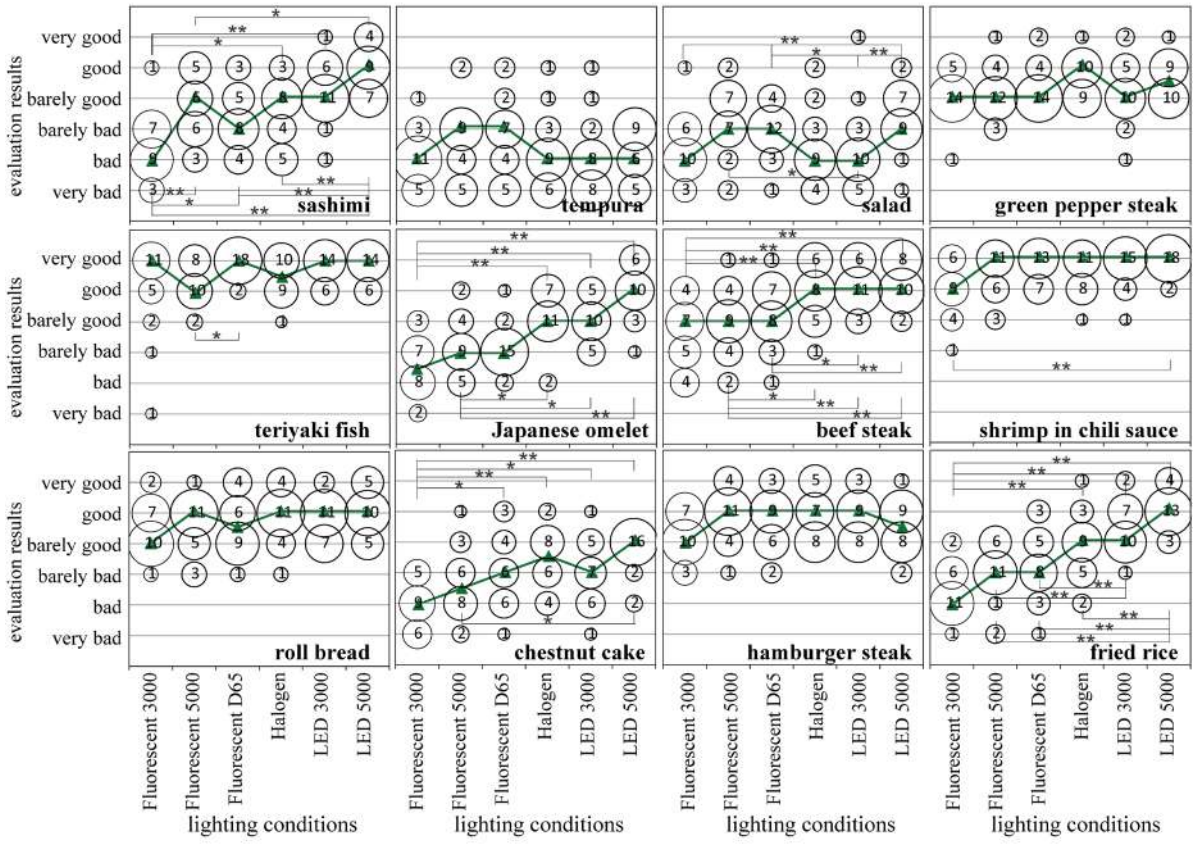

Figure 7 Evaluation results of glossiness under each lighting condition (*p<0.05, **p<0.01)

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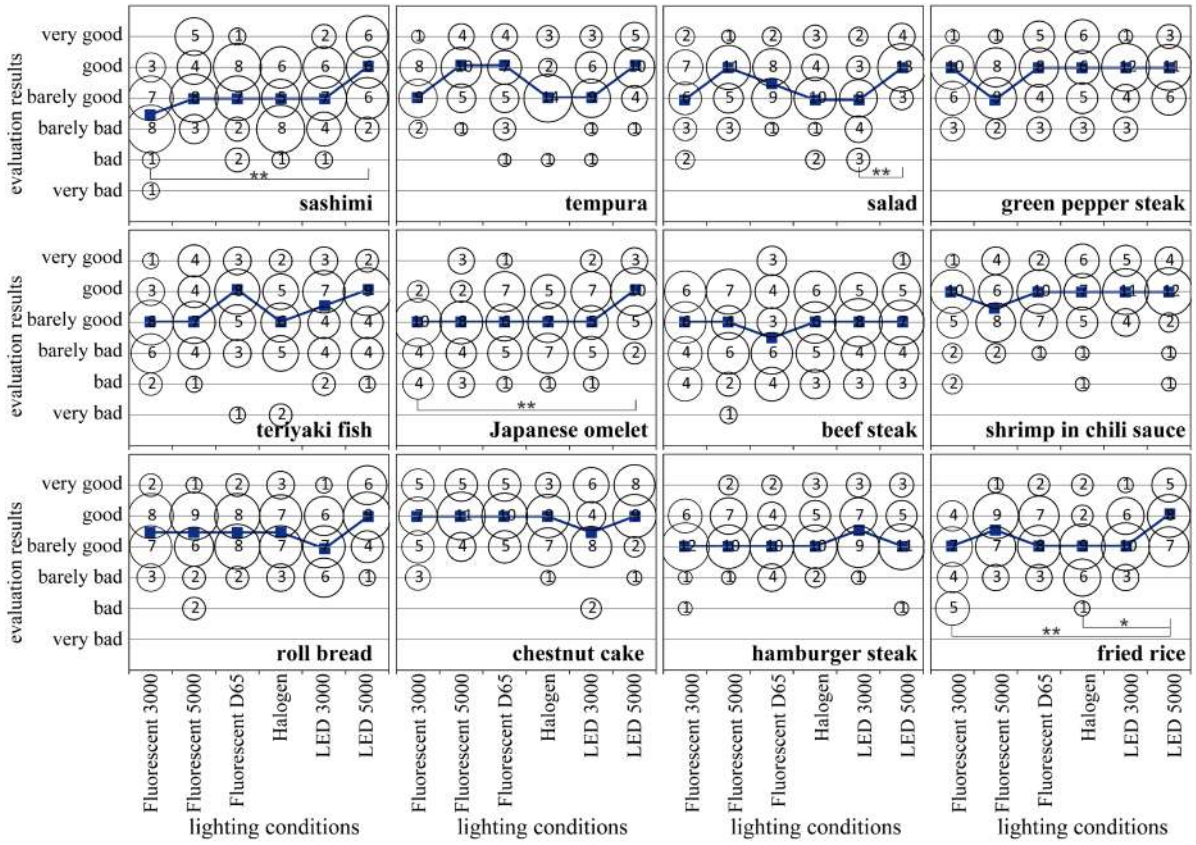

Figure 8 Evaluation results of convexo-concave perception under each lighting condition (*p<0.05, **p<0.01)

Table 3 Standardized partial regression coefficient

Food dishes	Color appearance	Glossiness	Convexoconcave
sashimi	.728***	.219***	−.075
tempura	.639***	−.026	.134
teriyaki fish	.519***	.143	.081
Japanese omelet	.708***	.228***	.078
hamburger steak	.505***	.212*	.014
beef steak	.474***	.134	.015
salad	.706***	.326***	−.126
green pepper steak	.573***	.299***	−.118
shrimp in chilli sauce	.588***	.238**	.113
fried rice	.762***	.084	.093
roll bread	.628***	.181*	.040
Mont-Blanc cake	.687***	.056	.100

*p<.05, **p<.01, ***p<.001

ance and the color rendering index (*Ra*) in Japanese dishes (sashimi, tempura, Japanese omelet and teriyaki fish), green pepper steak and roll bread whereas little correlation in Mont-blanc cake and hamburger steak.

(3) The surface property of the food is a more influential factor than the lighting condition, though directional lighting makes some dishes look glossy.
(4) Convexo-concave perception does not affect the visual palatability of foods.
(5) Color appearance is an important visual factor for the visual palatability of food dishes.
(6) Visual palatability of the raw food dishes and the dishes with sauce can be affected by both color appearance and glossiness.

In future studies, more factors such as SPDs of light source and some index of the color quality should be taken into consideration in analyzing the lighting conditions for making the food dishes palatable.

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