

# With a hint of Sudachi: food plating can facilitate the fondness of food

Nao Kokaji (✉ [kokajinao@keio.jp](mailto:kokajinao@keio.jp))

Keio University <https://orcid.org/0000-0001-6982-5500>

Masashi Nakatani (✉ [mn2598@sfc.keio.ac.jp](mailto:mn2598@sfc.keio.ac.jp))

Keio University <https://orcid.org/0000-0002-0749-2883>

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## Research Article

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# Abstract

Among the senses of food, our sense of taste is significantly influenced by our perception. In appetite science, previous research reported that when we make estimate the quality in daily life, we rely considerably on visual information (Carlos et al., 2012). In this study, we focused on the multimodal mental imagery (Nanay, 2018) evoked by the visual information of food served on a plate and examined the effect of the peripheral visual information: garnish, on the sensory impression of the main dish. We conducted a sensory evaluation experiment to evaluate the impressions of food photographs and structured the sensory values using multivariate analysis. We found that the appearance of the garnish placed on the plates close to the main meal contributes to appetite arousal. Here we show that color, moisture, and taste (sourness and spices) play a major role in the decision. In order to arouse one's appetite, it is important to make the main dish appear warmer. Our results can be used to modulate eating experience and appetite arousal. Applying these results for meals can contribute toward making the dining experience more attractive by superimposing visual information on it with XR technology, or by presenting real appropriate garnishes.

## Introduction

Visual information on food significantly influenced our daily life. For example, Carlos et al (2012) suggested that luminance distribution affects the judgment of freshness perception of strawberries; Murakoshi et al (2013) further showed that changes in luminance distribution and visual freshness perception correlate with deterioration time even when there are individual differences in foods. These studies reported a significant relationship between freshness and the desire to eat.

Main dishes refer to dishes whose main ingredients are sources of protein such as meat, fish and soybeans which play an important role in a balanced diet of nutrients, including the supply of high-quality protein (Gabriel et al, 2018). The main dish used in this experiment was fried chicken (Karaage in Japanese), whose garnishing ingredients are frequently placed next to the main dish. This is the national dish of Japan. Deep-fried dishes, such as fried chicken, contain fat (Marangoni et al, 2015), which should be consumed by elderly people and can provide a large amount of energy in a small quantity.

The sense of sight plays a major role in determining what consumers find attractive (Schifferstein et al, 2020). For instance, when the food is presented in a more pleasant way, people enjoy the food on the plate more (Zellner et al., 2014). Zellner et al. (2011) have also shown that neatly served foods are preferred over foods that are served less neatly.

Recent food studies have investigated how appetite can be aroused not only by the sense of taste but also by the sound, color, shape of the plate (Roballey et al., 1985). For example, increasing the visual contrast on a plate (e.g. changing the color of the plate) has been reported to significantly increase food and drink intake in patients with Alzheimer's disease (Tracy et al., 2003). Almost 40% of Alzheimer's patients experience weight loss, which is partly due to a loss of the ability to distinguish color

distinctions. Using plates and glasses that contrasted with the food increased food consumption by 25% and beverage consumption by 84%.

There have been studies of appetite arousal and surrounding colors and other factors; however, few cases investigate the significance of the immediate element of the surrounding environment of the main dish: the garnish. Therefore, this study tested the effect of the peripheral visual information, garnish, on the sensory impression of the main dish. We conducted a sensory evaluation experiment to study the impressions of food photographs and conducted multivariate analysis to structure the sensory values.

In this paper, we define a garnish as a solid that is added to the dish to decorate and enhance the taste of a dish. Condiments such as mayonnaise and other sauces were excluded. The number of ingredients does not refer to the number of pieces, but rather to the number of ingredients placed in the margins, excluding the main dish.

## Methods

### *Participants:*

The study participants included 15 students (11 women and 4 men; mean age, 22.0 years; SD, 1.37 years; age range, 21–26 years). Each participant had normal color vision and normal or corrected-to-normal visual acuity. The SFC Research Ethics Committee on Human Experimentation of Keio University, Shonan Fujisawa Campus (approval # 302) approved the experimental protocol. Informed consent, in writing, was collected from each participant prior to the experiment.

### *Stimuli:*

We created 26 types of stimuli, including the no-garnish plate: unchanged plates and main dish (fried chicken). The 25 types of garnish included ingredients, such as lemon and parsley, which are commonly used for garnishing. Additionally, we used seaweed, rakkyo, and sweet ingredients, which are uncommonly used. The ingredients were selected based on the results of a 10-participant pilot study with 30 types of garnish. Of these, 25 were chosen from the perspective of color, taste, and nutrition.

### *Procedures:*

Participants evaluated each of the 26 images using a Visual Analogue Scale (VAS). The 11 adjective pairs are presented below. The order of the stimuli was randomized across participants, and they could view the reference images at any time during the experiment. They provided their evaluations on a full-screen browser using Google Forms (Google LLC).

The eleven adjective pairs used in sensory evaluation:

☒ Freshness/fresh - not fresh

☒ Drying/dry - not dry

- ☒ Wetness/wet - not wet
- ☒ Warmth/warm - not warm
- ☒ Sourness/sour - not sour
- ☒ Sweetness/sweet - not sweet
- ☒ Saltiness/salty - not salty
- ☒ Looking/nice-looking - nasty looking
- ☒ Fondness/like - dislike
- ☒ Deliciousness/tasty - not tasty
- ☒ Appetite/want to eat - do not want to eat

## **Statistical analysis**

### ***Factor analysis***

We analyzed the eleven adjectives. The factor analysis employed the principal component method and varimax rotation. For multivariate analysis, we used Microsoft Excel (Version 16.44) and SPSS Statistics (Version 26.0.0.1). The data were collected using Google Forms (Google LLC) and organized. The mean values were calculated using Excel (Microsoft Corporation).

### ***Multiple regression analysis***

We applied multiple regression analysis to the values and excluded “looking,” “fondness,” “deliciousness,” and “appetite,” which were positioned as higher-order variables, and we conducted multiple regression analysis using the factor scores.

### ***Principal component analysis***

We also conducted a principal component analysis of the covariance matrix without rotation.

### ***Cluster analysis***

To clarify how the types of garnish were classified, we conducted a cluster analysis (Ward Linkage) using the principal component scores of PC1 and PC2.

## **Result**

### ***Factor analysis***

The factor loadings were 80.7 %, and Table 1 lists each factor's cumulative contribution rates. Factor 1 was the "warm and non-sweet factor." This factor was affected by the warmth and appearance of the dishes. Appetite and favorability were associated with warmth and good appearance. Factor 2 was the "fresh and refreshing factor" where wetness, freshness, and sourness simultaneously occurred. These factors affect appetite. In terms of sourness and freshness in the same factor, why lemons are often used as garnish was clarified. Factor 3 was the "saltiness factor." In the preliminary questionnaires of this experiment, lemon was the first that came to mind when asked about fried chicken's garnish (Supplemental Table 1). Additionally, we calculated means (standard deviations) and ranking for "appetite" (Supplemental Table 1). Based on the factor analysis and Table 1, boiled eggs, bread, cookies, and mixed nuts, which contain less moisture, are less likely to arouse appetite. Thus, choosing a moisturized garnish might arouse appetite. The factor scores were standardized such that the mean was 0 and standard deviation was 1 for each factor (Table 1).

### ***Multiple regression analysis***

To investigate the factor that aroused appetite, we performed multiple regression analysis using the factor scores, which excluded "looking," "fondness," "deliciousness," and "appetite," which were positioned as higher-order variables (Table 1). A VIF of 10 was obtained (Table 2). This result is shown in the path diagram in Figure 2. According to these analyses, Factor 1 and 2 scores had a statistically significant effect on appetite. Moreover, Factor 2 had a greater influence on appetite based on the high correlation coefficient scores. Thus, temperature and taste on the balance of flavors were significantly related to appetite.

### ***Principal component analysis***

Principal component analysis was conducted on all 11 variables, divided into two layers: physical and sensitivity factors. The principal component loadings were analyzed by the principal component with the variance-covariance matrix.

#### ***Physical Factors: dryness / wetness / warmth / sourness / sweetness / saltiness***

Two main principal components were identified (Table 3). PC1 extracted "moisture," "sourness," and "saltiness," while PC2 extracted "sweetness" and "coolness." We named PC1 the "complementary moisturization and refreshment component," and PC2 was the "strong influence of sweet garnish."

#### ***Sensitivity Factors: freshness / deliciousness / looking / fondness / appetite***

Only PC1 was extracted from the sensitivity factors (Table 4). PC1 contained "good looking," "appetite," "delicious appearance," "palatability," and "freshness." Therefore, PC1 indicates "freshness off the kitchen."

*Physical factors and sensitivity factors: drying / wetness / warmth / sourness / sweetness / saltiness / freshness / deliciousness / looking / fondness / appetite*

We conducted a principal component analysis of the physical and sensitivity factors (Table 5). PC1 extracted “good appearance,” “delicious,” “fond,” “appetite,” and “non-sweet,” while PC2 extracted “sourness” and “saltiness.”

The number of axes of the principal components was determined by referring to the scree plot (the horizontal axis represents the principal components, and the vertical axis represents the eigenvalues) (Supplemental Figure 1). The cumulative contribution up to PC2 accounted for 82.0 % of the total contribution, indicating that it exceeded 80.0 %. From this, the number of axes in the principal component was determined to be two. PC1 can be regarded as representing “freshness off the kitchen,” while PC2 represents “balance of flavors.” Principal component scores were calculated. It was standardized so that the mean was 0 and the standard deviation was 1 for each factor (Table 5).

Among the types of garnish, sudachi (citrus fruit) was found to be the most suitable for balancing the taste of the main dish (fried chicken) and make it look like it was more freshly off the kitchen. Lemon was found to be a suitable garnish for the main dish. Furthermore, we created a scatter plot based on the principal component scores and superimposed the images of the main dish and the garnish on the two-dimensional plane to visualize the relationship between the main dish and garnish (Figure 3).

### ***Cluster analysis***

Figure 4 shows the dendrogram of the cluster analysis (Ward Linkage) using principal component scores of PC1 and PC2. It classifies the 26 types of garnishes into 3 clusters. There are three main clusters: “color,” “dryness and taste,” and “moisture and taste.” Besides, coriander / basil / lettuce / parsley falls under the green vegetable cluster that we named the “green cluster” and bread / cookie / mixed nuts cluster and chocolate / raisins cluster, which we named “dry and sweet cluster.” The sudachi / lemon cluster was named the “moist and sour cluster.” Thus, the three main clusters included: “green cluster,” “sweet, sour, and spice cluster,” and “wet and dry cluster.”

## **Discussion**

The multivariate analysis revealed four elements that changed the participants’ impressions of the main dishes. The factor and cluster analyses showed that color, moisture, and taste (sourness and spiciness) play a major role in the impressions of main dishes. Visual attributes, for example the color of the plate, affected the sweetness intensity, perceived flavor, and overall preference of the dish. A study by Piqueras-Fiszerman et al. (2012) showed that a strawberry-flavored mousse served from a white plate was perceived as 15% more intense, 10% sweeter, and was 10% more liked when compared to the same dessert served from a black plate. Evidence for physiological changes to the food because of the color,

shape, and material of the tableware, such as plate and cutlery is also provided from Spence et al.'s 2012 study. This shows that not only the main dish but also the food plating and cutlery can modulate an eating experience. In this research, the multiple regression and principal component analyses indicated that, to arouse one's appetite, it is important to make the main dish appear warmer. Additionally, sour and moist garnishes can affect the appetite, because they can balance the flavors of the main dish.

The multivariate analysis results can be linked to the development of methods implemented to modulate eating experiences and appetite arousal. For fried foods (e.g. fried chicken), we found ways in which the appearance of the meal contributes to the arousal of one's appetite. Current research methodology can be further applied in studies of not only fried food but also boiled, grilled, stir-fried, and steamed food. Methods in which the appearance of a meal contributes to appetite stimulation and the design guidelines for meals can contribute toward making meals more attractive through the superimposition of information with XR technology, such as augmented reality (AR) and virtual reality (VR), or by presenting real objects (Figure 5). Previous research reported that the standard deviation of the luminance distribution of food images influences the perceived visual texture and flavor experience by using AR (Junya et al., 2020). The development of a real-time modification system without an AR marker could be applied to modify garnishes or the color of dishes.

Visual appeal and presentation of a dish can modulate the appetite of those eating it. Several studies have pointed out the importance of the visual presentation of food (i.e., food plating) in the perception of appetite (Michel et al., 2014). The current study supports the claims from previous research and the importance of a garnish. Our exploratory factor analysis showed the hypothetical model that describes the structural relationship between the induced cross-modal perception from visual presentations of food and appetite. Using structural equation modeling (SEM), we plan to conduct another study to test this hypothesis and quantify the overall structures. Additionally, to generalize our claim, further research should include the analysis of individual differences between participants.

Food garnish plays an important role both explicitly and implicitly. Freshness can be inferred from image statistics of the food (Arce-Lopera et al., 2012, 2015), and the magnitude of subjective freshness correlates with the parameters of the image statistics (mean, standard deviation, skewness, and kurtosis). In this study, the subjective ratings of freshness can influence the appetite of the person for the main food of the dish (Figure 2). If the perception of the garnish placed next to the main food could also affect appetite, we would be able to modulate appetite by changing the visual impressions created by the garnish. This addressed question will be pursued in further studies.

## **Declarations**

### **Author Contributions**

NK conducted experiments, data analysis and manuscript writing. Both authors conceived and wrote this manuscript and MN supervised this research project.

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## Conflict of interest

We have no conflict of interest to declare.

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## Tables

Tables 1-5 are available as downloads in the Supplementary Files section.

## Figures

Figure 1



Figure 1

Visual stimuli used in sensory evaluation experiments. We created 26 types of stimuli, including the no-garnish plate: unchanged plates and main dish (fried chicken). The ingredients were selected based on the results of a 10-participant pilot study with 30 types of garnish. Of these, and 25 were chosen from the perspective of color, taste, and nutrition.

Figure 2

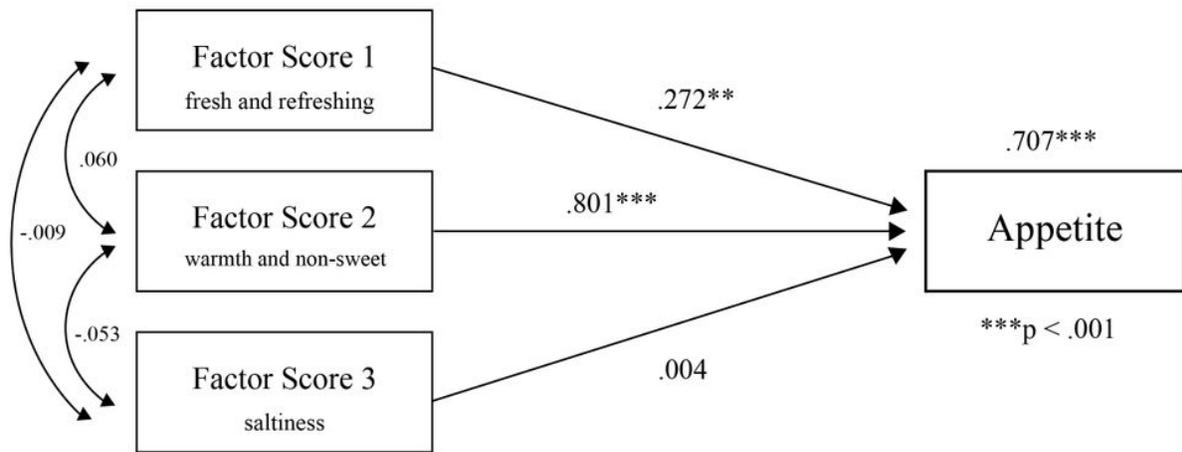


Figure 2

Factor 2 has more influence on appetite from the high correlation coefficient scores. We named Factor 1 the “fresh and refreshing factor.” Factor 2 was the “warm and non-sweet factor” and Factor 3 was the “saltiness factor.”

Figure 3

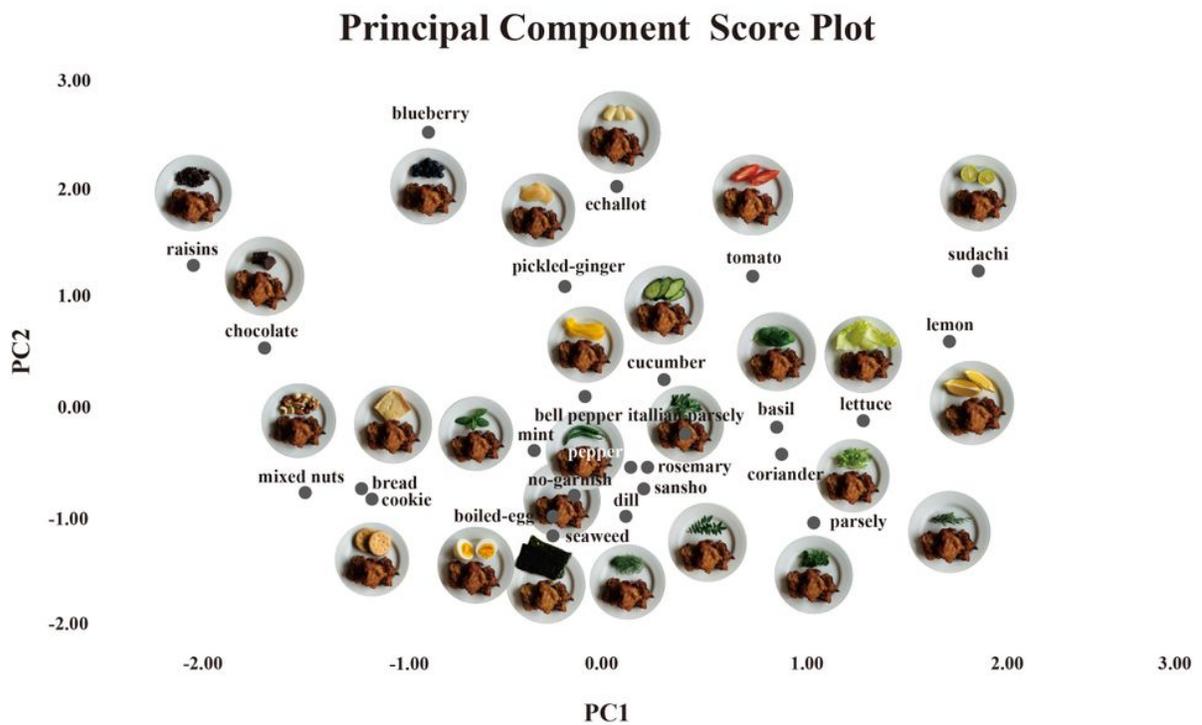


Figure 3

We created a scatter plot based on the principal component scores and superimposed the images of the main dish and the garnish on the two-dimensional plane to visualize the relationship between the main dish and the garnish. Similar-colored garnishes were located close together in this plot. The result of the sensory evaluation showed that sudachi (citrus fruit) was the most suitable one to balance the taste of the main dish.

Figure 4

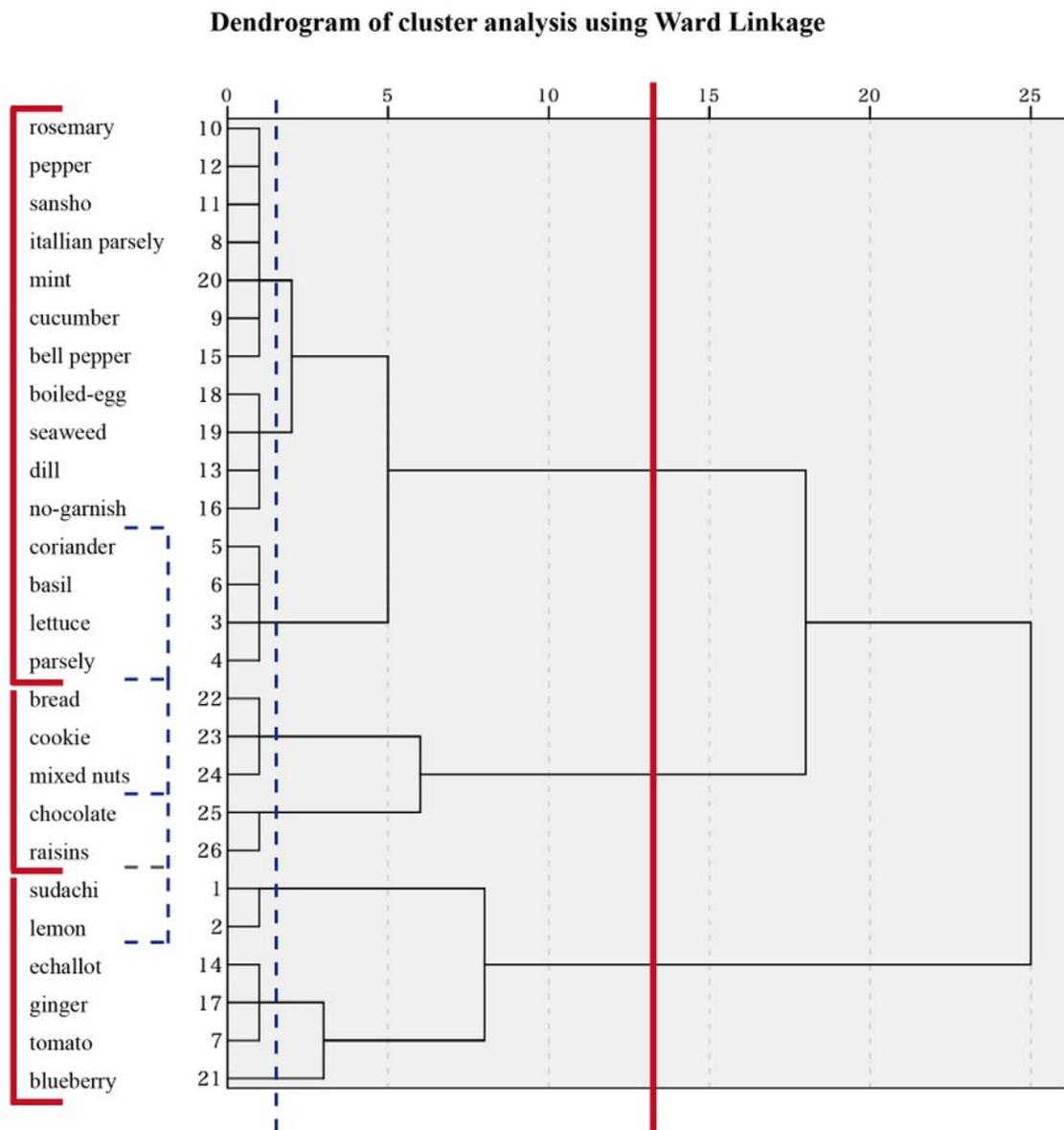


Figure 4

Cluster analysis classified the 26 types of garnish into 3 clusters. The solid line indicates three main clusters, and the dashed line shows more precise clusters in this figure.

Figure 5

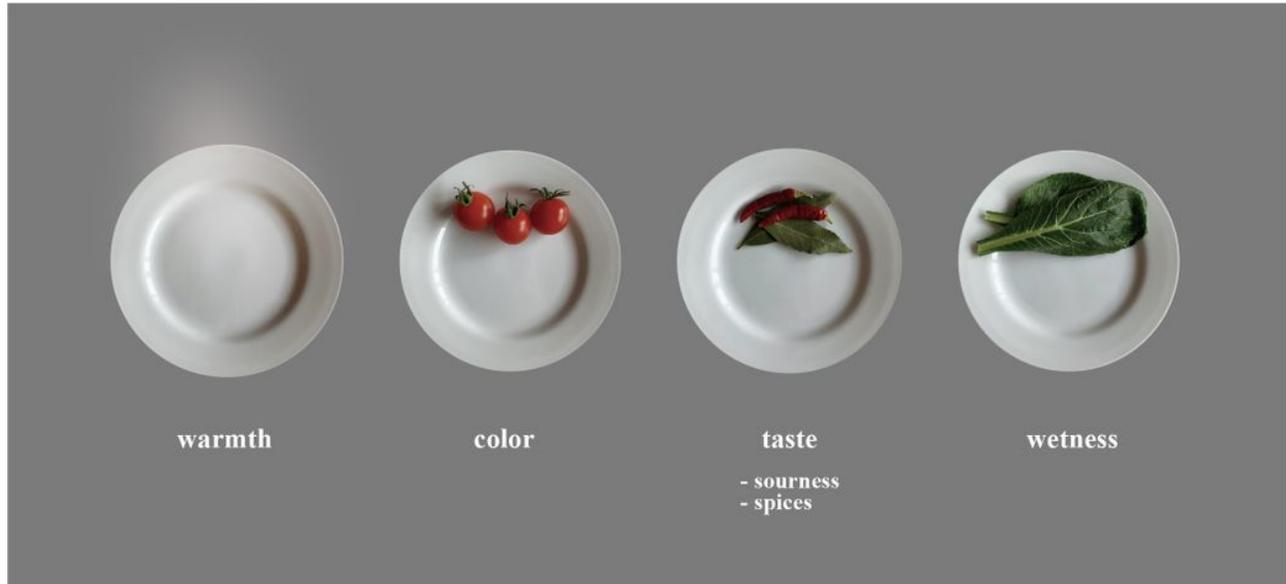


Figure 5

Four representative elements that change the impressions on the main dishes. The results of multivariate analysis showed that color, taste (sourness and spices), and moisture significantly affect the decision. Additionally, sour and moist types of garnish balance the taste combined with the main dish. In order to arouse appetite, it is important to make the main dish appear warmer, even if it is not fresh.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementalFigure1.jpg](#)
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- Table4.jpg
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