8-2023

How does increasing the darkness of a plate affect the perception of both bitter and sweet flavors?

Jessica Williams
University of Arkansas, Fayetteville

How does increasing the darkness of a plate affect the perception of

both bitter and sweet flavors?

Jessica Williams

University of Arkansas

Mentor: Dr. Han-Seok Seo

Committee: Dr. Han-Seok Seo (Chair), Dr. Scott Osborn, and Dr. Yao-Chin Wang

Effect of Plate Darkness on Food Perception

Table of Contents

Effect of Plate Darkness on Food Perception

Abstract

Consumer perception and acceptance of food items have been found to be affected by both intrinsic and extrinsic cues. Previous studies have shown that plate colors can modulate consumer perception of tastes or flavors. Only a few studies, however, have investigated how varying color values (e.g., darkness) alter consumer perception of tastes or flavors in food items. This study aimed to determine whether the change in the black to white ratio of plate color can affect consumer perception or acceptance for brownie items. A total of 210 participants were randomly assigned to one of five groups. Each participant was asked to taste two different brownies, a sweet-dominant and a bitter-dominant, on one of five different colored plates and evaluated each sample in terms of perception and acceptance. The plates varied in darkness, including white, light gray, medium gray, dark gray, and black. The results of this study showed no significant effects of the plate darkness levels on perception and acceptance of either brownie sample. In conclusion, this study provides empirical evidence that the darkness levels of plates are minimal in consumer perception or acceptance of brownie samples.

Effect of Plate Darkness on Food Perception

1. Introduction

Sensory perception of food and beverages has been known to be impacted by extrinsic cues, which are not a physicochemical part of the food and beverages themselves (Hasenbeck et al., 2014; García-Segovia et al., 2015; Piqueras-Fiszman & Spence, 2015; Beekman et al., 2021). These extrinsic cues include information gathered from the consumption environment, such as plates, cups, product labels, and cutlery items (Spence et al., 2012). For example, hedonic ratings of cold coffee (Beekman et al., 2021) or cold tea (Pramudya et al., 2021) differed with drinking conditions using different types (e.g., materials) of straws or lids. Previous research also revealed a relationship between perceived intensity of coffee flavor and the color of the mug in which it was served (Van Doorn et al., 2014), suggesting how color cues greatly impact food perception. Associations between certain colors and flavors were found to influence the perception of different foods (Koch & Koch, 2003). For example, if some individuals associate brown color with sweet taste, they will assume a brown colored food would be sweeter than its white counterpart. Thus, it would be interesting to find out whether the intensity of the color surrounding the food itself plays a part in its perceived flavor and taste, especially sweet taste because excessive intake of sugar is related to a high probability of chronic disease (Rippe & Angelopoulos, 2016).

There has been previous research conducted validating the claim that plate colors impact taste perception of food samples (Piqueras-Fiszman et al., 2012; Stewart & Gross, 2013). Two previous studies investigated the effect of black and white plates on sweetness perception. One evaluated cheesecake on white versus black plates and found the white plate had a greater impact on perceived sweetness intensity (Stewart & Gross, 2013). The other study presented mousse samples on both black and white plates and found a similar result where the samples were rated sweeter when presented on a white plate (Piqueras-Fiszman et al., 2012). Interestingly, a separate

Effect of Plate Darkness on Food Perception

study found when a chocolate flavored dessert was served on black plates it was perceived to have a stronger flavor (Piqueras-Fiszman et al., 2013). Color cues and their association with specific flavors could be one explanation of that (Zampini et al., 2007), in this case black being associated with chocolate.

The color of a plate has also been shown to exhibit no significant effect. One specific study investigated how cup colors affected perceived sweetness in beverage samples (Schifferstein, 2009). More specifically, Schifferstein (2009) showed that while people initially expected the beverage served in the pink cup to be sweeter, that assumption did not carry over when they tasted the product. Another study also showed that the color of a cup did not affect the sweetness of the beverage served in it when looking at red or black cups (Mielby et al., 2018). In a restaurant setting study, it was shown that when it came to chemosensory attributes it was the food product itself that held more sway than the color of the plates (Piqueras-Fizman et al., 2013). Those studies show conflicting arguments on background color and how much impact it has on perception.

Participant-related factors have also been shown to influence taste perception. For example, taste perception or their association with color cues has been found to vary with participants' abilities to distinguish colors (Jaint et al., 2010) and their demographic factors (Wan et al., 2014). Gender factor, specifically, has been shown to influence color perception, with women seeming to have a better capability of distinguishing red and green hues and men having a heightened sensitivity to the brightness of a color (Jaint et al., 2010). Demographic factors, such as gender, socioeconomic status, and ethnicity, have also been shown to influence food choice (Deshmukh-Taskar et al., 2006), thereby affecting consumers' flavor preferences and perhaps even their flavor perception. Women have also been shown to have higher cravings for sweet foods (Chao et al., 2017) which could result in them preferring the dessert they perceive as the sweetest. Personality

Effect of Plate Darkness on Food Perception

traits have also been found to affect taste preferences (Terasaki & Imada, 1988; Saliba et al., 2009; Sagioglou & Greitemeyer, 2015; Samant & Seo, 2019; Beekman & Seo, 2023). Sweet taste preference has been linked to the personality traits of empathy and agreeableness (Saliba et al., 2009), bitter taste preference has been linked to "malevolent personality traits" (Sagioglou & Greitemeyer, 2015), and spicy taste preference has been linked to more extroverted and adventurous personalities (Terasaki & Imada, 1988).

Food-evoked emotions can also play a role in consumer acceptance for food items (Cardello et al., 2012; Samant & Seo, 2019; Singh & Seo, 2020; Pinsuwan et al., 2022). Positive emotions were felt after participants consumed samples they enjoyed, and participants experienced negative emotions after tasting samples they did not enjoy (Samant et al., 2017). Samant et al. (2017) also found that the relationship between the negative emotions and the disliked food was greater than that of the relationship between the positive emotions and liked foods. Positive emotions were also found to positively correlate with enjoyment of a sample, and negative emotions were found to negatively correlate with enjoyment of a sample (Cardello et al., 2012), indicating a potential to predict if consumers will prefer a food based on their emotions toward that food.

The above studies illustrate the potential for plate colors to evoke taste expectations and therefore, influence taste perception of the food or beverage consumed. However, there is also some slight controversy and disagreement over the extent to which color has an impact. There has been no study that examines the degree to which white or black color begins to evoke sweetness or bitterness taste expectations as well. Therefore, this study aimed to determine whether increasing a level of darkness (or blackness) or lightness (or whiteness) in a plate color could alter consumer perception, acceptance, and emotional responses toward brownie samples. Based on the

Effect of Plate Darkness on Food Perception

findings in existing literature, it was hypothesized that plate colors would have an impact on the perception of both the bitter and sweet tastes with increasing blackness leading to a more bitter perception and increasing whiteness leading to sweeter perception. The following sections will describe in detail the study conducted to determine the extent to which darkening the plate color influences the taste perception of both sweet and bitter brownie samples.

Effect of Plate Darkness on Food Perception

2. Materials and Methods

A total of 210 volunteers were recruited from the NW Arkansas area using a consumer profile database of the University of Arkansas Sensory Science Center (Fayetteville, AR, USA). Students were also recruited on the campus via flyers and announcements. The male to female ratio was 30:70 with the mean age of 31 years old. The criteria for inclusion were no preexisting conditions that could impact taste, smell, or sight, no chronic diseases, no food allergies, and a self-reported liking of brownies. Participants were asked to refrain from eating, drinking (except for drinking water), and cigarette smoking for 2 hours prior to their participation. Prior to a main study, participants were asked to rate their hunger/fullness on a 9-point category scale ranging from 1 (extremely hungry) to 9 (extremely full). They were also asked to rate their feelings on a 9-point category scale ranging from 1 (extremely bad) to 9 (extremely good).

2.1. Sample Preparation

The brownie samples were prepared the night before each test day. The recipes for each of the two types were as follows:

Bitter-dominant brownie: 2/3 c canola oil, 2/3 c cocoa powder, ½ c ap flour, ¼ tsp baking powder, ½ tsp salt, 3 eggs, 1 tsp vanilla, 60g powder sugar, 71g brown sugar.

Sweet-dominant brownie: 1 1/3 c canola oil, 1 1/3 c cocoa powder, ½ c ap flour, ¼ tsp baking powder, ½ tsp salt, 3 eggs, 108g powder sugar, 128g brown sugar.

The process began by heating up the oil and mixing in the coco powder and allowed to sit while the other ingredients were combined. The sugar and the eggs were whisked together until they became a lighter color, and then the salt, vanilla, and baking powder were stirred in. Then 1/3 of the coco and oil mixture was mixed in. After that 1/3 of the flour was folded in. Alternating

Effect of Plate Darkness on Food Perception

between the coco and oil mixture and the flour mixture until it is all incorporated. The mixture was poured into prepared 9 by 9 glass baking dishes. The dish was prepared by covering lightly with oil then dusting with coco powder. Then they were baked. They were baked at 325 ºF (162.8 ºC) convection setting for 30 minutes for the bitter ones and 40 minutes for the sweet ones. The finished brownies were cut into 1.5 by 1.5-inch squares and stored in airtight containers overnight at room temperature. Table 1 shows color characteristics of the two brownie samples.

2.2. Plates

Five different plate colors were used. The plates were square in shape and had a length of 4.5 in X 4.5 in. The plates were different in terms of color cue, especially lightness (or darkness). Table 1 shows the five plates' color characteristics measured by colorimeter (MiniScan XE Plus, HunterLab, Reston, VA, USA). The "L" reading describes the darkness of the sample with a lower reading being darker, the "a" represents green to red, and the "b" represents blue to yellow.

2.3. Procedure

People were randomly assigned to one of the five groups (A-E) the day they came in. There was a total of six days of data collection over five weeks. Each group corresponded to a different plate color. Each participant received two brownie samples, bitter-dominant and sweet-dominant, in a monadic sequential fashion; a serving order of the two brownie samples was randomized. The plates were covered in transit by a metal cover from behind the screed prep area to ensure other groups did not see the other plate colors. Participants were asked to evaluate each sample placed on one of the five plates, identified with a three-digit code, on a 9-point intensity scale with respect to sweetness intensity, bitterness intensity, and chocolate flavor intensity, respectively. They were

Effect of Plate Darkness on Food Perception

also asked to evaluate each sample on a 9-point hedonic scale in terms of appearance liking, flavor

liking, texture liking, and overall liking. Following those questions, they were asked to report their

emotional responses to each sample on the EsSense Profile® questionnaire (King & Meiselman,

2010) using a Check-All-That-Apply method. The participants were given 3 to 5 minutes between

sample presentations for cleansing their palate with unsalted crackers (Nabisco Premium Unsalted

Tops Saltine Crackers, Mondelēz Global LLC, East Hanover, NJ, USA) and spring water (Clear

Mountain Spring Water, Taylor Distributing, Heber Spring, AR, USA).

2.4. Data analysis

Data analyses were performed using SPSS 26.0 for Windows™ (IBM SPSS Inc., Chicago,

IL, USA) and XLSTAT statistical software (Addinsoft, New York, NY, USA). An analysis of

variance (ANOVA) was conducted to test whether the five groups (A to E) differed in terms of

hunger/fullness and feelings. A two-way analysis of variance, treating plate color and brownie type

as fixed effects, was conducted to determine whether plate colors could affect consumer perception

and liking of brownie samples. If a significant difference was indicated by the ANOVA, post hoc

multiple pairwise comparisons were conducted using Tukey's honest significant difference (HSD)

tests. Cochran's Q-test was also performed to determine whether the proportions of selection by

participants for individual terms of the CATA question could differ as a function of the plate color

in either brownie sample. A correspondence analysis was also performed to visualize the

association between test samples with plate colors and evoked emotions. A statistically significant

difference was defined at $P < 0.05$.

Effect of Plate Darkness on Food Perception

3. Results

The five groups (A to E) did not differ in terms of hunger/fullness ($P = 0.18$) and feelings ($P = 0.93$). Participants in the five groups reported that on average, they were slightly hungry and felt moderately good.

3.1. Effects of plate colors on sensory perception of brownie samples

As shown in Tables 2 and 3, there were no significant interactions between brownie types and plate colors with respect to sweetness intensity, bitterness intensity, and chocolate flavor intensity (for all, $P > 0.05$). The two brownie samples differed significantly in terms of sweetness intensity, bitterness intensity, and chocolate flavor intensity (for all, $P < 0.05$). While sweet-dominant brownie showed higher ratings of sweetness and chocolate flavor intensities, bitter-dominant brownie exhibited higher ratings of bitterness intensity than the counterpart (for all, $P < 0.05$) (Figure 1). While the plate colors did not differ in sweetness intensity and chocolate flavor intensity, they differed significantly in bitterness intensity ($P = 0.04$). However, *post hoc* multiple pairwise comparison tests revealed no significant differences ($P > 0.05$).

3.2. Effects of plate colors on consumer acceptance of brownie samples

There were no significant interactions between brownie types and plate colors with respect to appearance liking, flavor liking, texture liking, and overall liking (for all, $P > 0.05$) (Tables 2 and 3). The two brownie samples differed significantly in terms of appearance liking, flavor liking, texture liking, and overall liking (for all, $P < 0.05$) with higher hedonic ratings of sweet-dominant brownie. No significant effects of plate color were observed in appearance liking, flavor liking, texture liking, and overall liking (for all, $P > 0.05$) (Table 2).

Effect of Plate Darkness on Food Perception

3.3. Effects of plate colors on emotional responses evoked by brownie samples

CATA analysis was conducted on the 39 different emotions evoked by both the bitter-dominant and sweet-dominant brownie samples served on five different plate colors. As shown in Table 4, four emotional attributes differed significantly with bitter-dominant brownie samples served on five different plate colors: "glad" (P = 0.048), "loving" (P = 0.017), "pleasant" (P = 0.036), and "pleased" (P = 0.012). *Post hoc* tests revealed no significant pairwise sample differences in the "glad" and "loving" emotions. The bitter-dominant brownie sample served on the gray plate evoked the "pleasant" emotion more frequently than the sample served on the dark gray plate. Also, the brownie sample served on the gray plate elicited the "pleased" emotion more frequently than the sample served on the light gray plate.

As shown in Table 5, while sweet-dominant brownie samples served on five different plate colors differed in the "tender" emotion (P = 0.042), *post hoc* multiple pairwise comparisons revealed no significant sample differences.

When combined all samples (two types of brownie sample × five different plate colors), a biplot of the correspondence analysis, accounting for 81.38 of the total variance, showed that the types of brownie sample (bitter dominant versus sweet dominant) exhibited a stronger impact on evoked emotions than the colors of plate. As shown in Figure 8, the two types of brownie samples were distributed along with X-axis (F1) of the biplot. While the bitter-dominant brownie samples were likely to differ with plate colors in terms of emotional attributes, the sweet-dominant brownie samples were likely to be similar.

Effect of Plate Darkness on Food Perception

4. Discussion

The results found no significant effects of the different plate colors on any of the sensory attributes in brownie samples. Interestingly, even when just the white and black plates were compared there was no effect. This suggests that brownie samples are not as susceptible to changes in background color of the plates which contradicts previous studies claiming that the black plate made the chocolate flavor intensity stronger (Piqueras-Fizman et al., 2013). However, it is worth noting that the brownie sample served with a gray plate was likely to be less bitter than the brownie sample served with a light gray plate or a dark gray plate, probably leading to higher proportions of "pleasant" and "pleased" emotions for the brownie sample with a gray plate than for the brownie sample with a light gray plate or a dark gray plate.

Something that might be interesting to look further into would be if there are certain foods that are more susceptible to extrinsic factors like plate color. For example, in a previous review of the literature, it can be noted that all the studies that showed significant results were tested on foods that were neutral in color and did not have very strong or complex flavors (Spence, 2018). The previous study by Piqueras-Fizman et al. (2012) used a sweet mousse dessert and a study done by Harrar and Spence (2013) saw results with the white yogurt. Both of those foods are slightly sweet but do not have as complex a flavor profile as a baked chocolate brownie product. Previously it has been suggested that color contrast could also be an explanation as to the differences noted (Zampini et al., 2007), but even when presented the sweet-dominant brownie which had a greater contrast between the darker plates than the bitter-dominant one there was no difference noted as well. Another addition could be the possibility of taking into consideration people's history with brownies, and how far the samples deviate from their expectations. Asking questions regarding plate color before seeing the plate without the food being presented on it could also affect how

Effect of Plate Darkness on Food Perception

someone likes the plate color. Gender factors also need to be explored in this topic. A study conducted by Funk and Ndubisi (2006) found for male consumers there was a higher impact of color significance when they chose automobile color. It was also found in a different study that when presented food under blue light men consumed a significantly less amount compared to the women, further suggesting that when it comes to food and color men are more sensitive to change (Cho et al., 2014). Further, Chellappa et al. (2017) found regarding blue light, men had stimulus response curves twice as high as the women's response curves. Based on previous findings, it would be interesting to conduct a further study to examine how gender factors can influence the effect of plate colors on sensory and emotional responses to food items.

It is also important to note that in this study not every person was able to taste the samples on each plate color, so that could also have influenced the results. Perhaps if each person tried on each of the different colors some differences may have been noted. Since taste and eating are such subjectable experiences there can be a lot of person-to-person differences that cannot be fully considered unless each person is able to experience each situation.

5. Conclusion

The present study found that for two prepared brownie samples, the colors, especially lightness/darkness, of the plate had no significant effect on the sensory aspects or the consumer liking aspects of the products. While bitterness intensity was different among the five plate colors, *post hoc* tests found no significant pairwise differences. No significant differences among the five plate colors were also observed in the ratings of sweetness intensity, chocolate flavor intensity, appearance liking, flavor liking, texture liking and overall liking. However, emotional responses to bitter-dominant brownie differed significantly among the five plate colors. The results suggest

Effect of Plate Darkness on Food Perception

that the type of food might have a big influence on its susceptibility to influence from surrounding forces like plate color. Therefore, a further study should be conducted to look further into the effects of plate color on sensory and emotional responses to food items over a wider range of food type.

Acknowledgements

References

Beekman, T.L., Huck, L., Claure, B., & Seo, H.-S. (2021). Consumer acceptability and monetary value perception of iced coffee beverages vary with drinking conditions using different types of straws or lids. *Food Research International*, *140*, 109849. DOI: 10.1016/j.foodres.2020.109849

Beekman, T.L., & Seo, H.-S. (2023). Development and validation of a food-related analysis-holism scale (F-AHS). *Journal of Food Science*, *88*, A205-A226. DOI: 10.1111/1750-3841.16504

Cardello, A., Meiselman, H., Schutz, H., Craig, C., Given, Z., Lesher, L., & Eicher, S. (2012). Measuring emotional responses to foods and food names using questionnaires. *Food Quality and Preference 24,* 243-250. DOI: 10.1016/j.foodqual.2011.12.002

Chao, A., Loughead, J., Bakizada, Z., Hopkins, C., Geliebter, A., Gur, R., & Wadden, T. (2017) Sex/Gender differences in neural correlates of food stimuli: a systematic review of functional neuroimaging studies. *Obesity Reviews, 18,* 687-699. DOI: 10.1111/obr.12527

Chellappa, S., Steiner, R., Oelhafen, P., & Cajochen, C. (2017). Sex differences in light sensitivity impact on brightness perception, vigilant attention, and sleep in humans. *Scientific Reports, 7,* 14215. DOI: 10.1038/s41598-017-13973-1

Cho, S., Han, A., taylor, M., Huck, A., Mishler, A., Mattal, K., Barker, C., & Seo, H. (2015). Blue light decreases the amount of food consumed in men, but not women. *Appetite, 85,* 111-117. DOI: 10.1016/J.appet.2014.11.020

Deshmukh-Taskar, P., Nicklas, T., Yang, S., & Berenson, G. (2006). Does food group consumption vary by differences in socioeconomic, demographic, and lifestyle factors in

young adults? The Bogalusa heart study. *Journal of American Dietetic Association, 107, 2,* 223-224. DOI: 10.1016/j.jada.2006.11.004

Funk, D., & Ndubisi, N. (2006). Colour and product choice: a study of gender roles. *Management Research News, 29,* 41-52. DOI: 10.1108/01409170610645439

García-Segovia, P., Harrington, R.J., & Seo, H.-S. (2015). Influences of table setting and eating location on food acceptance and intake. *Food Quality and Preference*, *39*, 1-7. DOI: 10.1016/j.foodqual.2014.06.004

Hasenbeck, A.; Cho, S.; Meullenet, J.-F., Tokar, T., Yang, F., Huddleston, E.A., & Seo, H.-S. (2014). Color and illuminance level of lighting can modulate willingness to eat bell peppers. *Journal of the Science of Food and Agriculture*, *94*, 2049-2056. DOI: 10.1002/jsfa6523

Jaint, N., Verma, P., Mittal, S., Singh, A., & Munjal, S. (2010). Gender based alteration in color perception. *Indian Journal of Physiology and Pharmacology, 54,* 366-370.

King, S.C., & Meiselman, H.L. (2010). Development of a method to measure consumer emotions associated with foods. *Food Quality and Preference, 21,* 168-177. DOI: 10.1016/j.foodqual.2009.02.005

Koch, C., & Koch, E. (2003). Preconceptions of taste based on color. *The Journal of Psychology, 137, 3,* 233-242. DOI:10.1080/00223980309600611

Lachin, J. (1981). Introduction to sample size determination and power analysis for clinical trials. *Controlled Clinical Trials, 2, 93-113*. DOI: 10.1016/0197-2456(81)90001-5

Meier, B., Moeller, S., Riemer-Pelts, M., & Robinson, M. (2012). Sweet taste preferences and experiences predict prosocial inferences, personalities, and behaviors. *American Psychological Association, 102, 1,* 163-174. DOI: 10.1037/a0025253

Mielby, C., Wang, Q., Jensen, S., Bertelsen, A., Kidmose, U., Spence, C., & Byrne, D. (2018). See, feel, taste: the influence of receptacle colour and weight on the evaluation of flavoured carbonated beverages. *Foods, 7,* 119. DOI: 10.3390/foods7080119

Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technology, 11, Suppl.,* 9–14.

Pinsuwan, A., Suwonsichon, S., Chompreeda, P., & Prinyawiwatkul, W. (2022). Sensory drivers of consumer acceptance, purchase intent and emotions toward brewed black coffee. *Foods, 11*, 180. DOI: 10.3390/foods11020180

Piqueras-Fiszman, B., Alcaide, J., Roura, E., & Spence, C. (2012). Is it the plate or is it the food? Assessing the influence of the color (black or white) and shape of the plate on the perception of the food placed on it. *Food Quality and Preference, 24,* 205-208. DOI: 10.1016/j.foodqual.2011.08.011

Piqueras-Fiszman, B., Giboreau, A., & Spence, C. (2013). Assessing the influence of the color of the plate on the perception of a complex food in a restaurant setting. *Flavour, 2,* 24. DOI: 10.1186/2044-7248-2-24

Piqueras-Fiszman, B., & Spence, C. (2015). Sensory expectations based on product-extrinsic food cues: An interdisciplinary review of the empirical evidence and theoretical accounts. *Food Quality and Preference, 40,* 165-179. DOI: 10.1016/j.foodqual.2014.09.013

Piqueras-Fizman, B., & Spence, C. (2012). The influence of the color of the cup on consumers' perception of a hot beverage. *Journal of Sensory Studies, 27,* 324-321. DOI: 10.1111/j.1745-459X.2012.00397.x

Pramudya, R.C., Singh, A., Seo, H.-S. (2021). A sip of joy: Straw materials can influence emotional responses to, and sensory attributes of cold tea. *Food Quality and Preference, 88,* 104090. DOI: 10.1016/j.foodqual.2020.104090

Rippe, J., & Angelopoulos, T.J. (2016). Relationship between added sugars consumption and chronic disease risk factors: current understanding. *Nutrients, 8,* 697. DOI: 10.3390/nu8110697

Sagioglu, C. & Greitemeyer, T. (2015). Individual differences in bitter taste preferences and associated with antisocial personality traits. *Appetite, 96,* 299-308. DOI: 10.1016/j.appet.2015.09.031

Saliba, A., Wragg, K., & Richardson, P. (2009). Sweet taste preference and personality traits using a white wine. *Food Quality and Preference, 2,* 572-575. DOI: 10.1016/j.foodqual.2009.05.009

Samant, S.S., Chapko, M., & Seo, H.-S. (2017). Predicting cosumer liking and preference based on emotional responses and sensory perception: A study with basic taste solutions. *Food Research International, 100,* 325-334. DOI: 1016/j.foodres.2017.021

Samant, S.S., Seo, H.-S. (2019). Personality traits affect the influences of intensity perception and emotional responses on hedonic ratings and preference rank toward basic taste solutions. *Journal of Neuroscience Research*, *97*, 276-291. DOI: 10.1002/jnr.24321

Schifferstein, H. (2009). The drinking experience: cup of content? *Food Quality and Preference, 20,* 268-276. DOI: 10.1016/j.foodqual.2008.11.003

Singh, A., & Seo, H.-S. (2020). Sample temperatures can modulate both emotional responses to and sensory attributes of tomato soup samples. *Food Quality and Preference, 86,* 104005. DOI: 10.1016/j.foodqual.2020.104005

Spence, C. (2015). Multisensory flavor perception. *Cell, 161*, 24-35. DOI: 10.1016/j.cell.2015.03.007

Spence, C., Harrar, V., & Piqueras-Fiszman, B. (2012). Assessing the impact of the tableware and other contextual variables on multisensory flavour perception. *Flavour, 1, 7.* DOI: 10.1186/2044-7248-1-7

Stewart, P., & Gross, E. (2013). Plate shape and color interact to influence taste and quality judgements. *Flavour, 2,* 27. DOI:10.1186/2044-7248-2-27

Terasaki, M., & Imada, S. (1988). Sensation seeking and food preferences. *Personality and Individual Differences, 9,* 87-93. DOI: 10.101610191-8869(88)990033-5

Van Doorn, G., Wuillemin, D., & Spence, C. (2014). Does the colour of the mug influence the taste of coffee? *Flavour, 3,* 10. DOI: 10.1186/2044-7248-3-10

Wan, X., Woods, A., van den Bosch, D., McKenzie, K., Velasco, C., & Spence, C. (2014). Cross-cultural differences in cross modal correspondences between basic tastes and visual features. *Frontiers in Psychology, 5,* 1365. DOI: 10.3389/fpsyg.2014.01365

Williams, E.J. (1949). Experimental designs balanced for the estimation of residual effects of treatments. *Australian Journal of Chemistry, 2,* 149-168. DOI: 10.1071/CH9490149

Zampini, M., Sanabria, D., Phillips, N., & Spence, C. (2007). The multisensory perception of flavor. Assessing the influence of color cues on flavor discrimination responses. *Food Quality and Preference, 18, 975-984*. DOI: 10.1016/j.foodqual.2007.04.001

Effect of Plate Darkness on Food Perception

Table 1. Color characteristics of two brownie samples and five plates used in this study

Category	Sample	L	a	b
Brownies	Bitter-dominant	23.43	8.18	7.00
	Sweet-dominant	30.32	13.44	15.48
Plates	White	88.38	-0.53	-3.48
	Light gray	67.82	-1.57	-0.7
	Gray	47.18	-2.83	0.43
	Dark gray	22.96	-4.09	2.02
	Black	6.71	-1.56	-1.71
Reference	Placemat	39.17	8.04	9.82

Effect of Plate Darkness on Food Perception

Table 2. A summary of the results of the analysis of variance showing the effects of brownie type and plate color and their interactions

Attributes	Brownie type (B)	Plate color (P)	B × P
Sweetness intensity	234.15 (< 0.001)	0.33 (0.86)	0.20 (0.94)
Bitterness intensity	239.75 (< 0.001)	2.51 (0.04)	0.31 (0.87)
Chocolate flavor intensity	26.95 (< 0.001)	0.87 (0.48)	0.32 (0.87)
Appearance liking	58.74 (< 0.001)	0.63 (0.64)	1.14 (0.34)
Flavor liking	413.84 (< 0.001)	1.08 (0.37)	0.29 (0.89)
Texture liking	623.30 (< 0.001)	0.57 (0.68)	0.77 (0.54)
Overall liking	587.24 (< 0.001)	1.61 (0.17)	0.74 (0.56)

Effect of Plate Darkness on Food Perception

Table 3. Mean ratings (± standard deviation) of sensory perception and liking for each brownie sample

	White	**Light gray**	**Gray**	**Dark gray**	**Black**
Bitter-dominant brownie					
Sweetness intensity	3.38 (1.64)	3.14 (1.75)	3.36 (1.51)	3.55 (1.81)	3.19 (1.55)
Bitterness intensity	6.69 (1.16)	6.67 (1.34)	6.33 (1.57)	6.98 (1.09)	6.36 (1.62)
Chocolate flavor intensity	5.81 (1.93)	5.38 (2.22)	5.81 (1.85)	5.50 (2.17)	5.33 (2.03)
Appearance liking	5.02 (1.79)	5.48 (1.95)	5.02 (2.27)	5.33 (2.13)	4.64 (2.17)
Flavor liking	4.12 (1.78)	3.83 (2.33)	4.19 (2.21)	3.74 (1.81)	3.90 (2.01)
Texture liking	2.64 (1.59)	2.93 (1.92)	2.93 (1.85)	3.10 (1.99)	3.33 (1.92)
Overall liking	3.69 (1.76)	3.31 (1.93)	3.88 (2.03)	3.29 (1.63)	3.81 (1.77)
Sweet-dominant brownie					
Sweetness intensity	5.67 (1.52)	5.60 (1.67)	5.79 (1.42)	5.71 (1.47)	5.76 (1.56)
Bitterness intensity	4.12 (1.84)	4.55 (1.56)	3.79 (2.04)	4.48 (1.85)	4.05 (1.61)
Chocolate flavor intensity	6.64 (1.43)	6.45 (1.33)	6.36 (1.38)	6.55 (1.23)	6.19 (1.21)
Appearance liking	6.26 (1.68)	6.60 (1.42)	6.38 (1.51)	6.43 (1.76)	6.79 (1.72)
Flavor liking	7.45 (1.15)	7.57 (1.15)	7.60 (1.08)	7.12 (1.53)	7.10 (1.59)
Texture liking	7.24 (1.65)	7.55 (1.65)	7.33 (1.28)	7.02 (1.96)	7.29 (1.86)
Overall liking	7.45 (0.92)	7.52 (0.92)	7.48 (0.86)	6.93 (1.66)	7.24 (1.57)

Table 4. A contingency table of the proportions of selection for emotional attributes among the bitter-dominant brownie samples served on the five plates with different colors

	White	Light gray	Gray	Dark gray	Black	*P*-value
Active	0.143 (a)[1]	0.071 (a)	0.095 (a)	0.024 (a)	0.143 (a)	0.315
Adventurous	0.167 (a)	0.095 (a)	0.095 (a)	0.095 (a)	0.167 (a)	0.681
Affectionate	0.024 (a)	0.024 (a)	0.095 (a)	0.024 (a)	0.024 (a)	0.308
Aggressive	0.238 (a)	0.190 (a)	0.167 (a)	0.190 (a)	0.143 (a)	0.852
Bored	0.143 (a)	0.214 (a)	0.167 (a)	0.286 (a)	0.167 (a)	0.434
Calm	0.095 (a)	0.119 (a)	0.214 (a)	0.095 (a)	0.143 (a)	0.465
Daring	0.167 (a)	0.095 (a)	0.119 (a)	0.071 (a)	0.048 (a)	0.448
Disgusted	0.452 (a)	0.500 (a)	0.333 (a)	0.548 (a)	0.405 (a)	0.300
Eager	0.143 (a)	0 (a)	0.095 (a)	0.048 (a)	0.048 (a)	0.103
Energetic	0.167 (a)	0.095 (a)	0.143 (a)	0.048 (a)	0.095 (a)	0.473
Enthusiastic	0.095 (a)	0.024 (a)	0.048 (a)	0.024 (a)	0.095 (a)	0.382
Free	0.071 (a)	0.024 (a)	0.071 (a)	0.024 (a)	0.071 (a)	0.615
Friendly	0.048 (a)	0.024 (a)	0.119 (a)	0.024 (a)	0.119 (a)	0.151
Glad	0.048 (a)	0.048 (a)	0.143 (a)	0 (a)	0.143 (a)	0.048
Good	0.143 (ab)	0.143 (ab)	0.310 (b)	0.071 (a)	0.167 (ab)	0.057
Good-natured	0.024 (a)	0.119 (a)	0.095 (a)	0.048 (a)	0.119 (a)	0.406
Guilty	0.048 (a)	0.071 (a)	0.071 (a)	0.024 (a)	0 (a)	0.437
Happy	0.024 (a)	0.071 (a)	0.167 (a)	0.048 (a)	0.119 (a)	0.112
Interested	0.238 (ab)	0.190 (ab)	0.286 (b)	0.048 (a)	0.167 (ab)	0.061
Joyful	0.048 (a)	0.024 (a)	0.071 (a)	0.024 (a)	0.071 (a)	0.716
Loving	0 (a)	0 (a)	0.071 (a)	0 (a)	0 (a)	0.017
Merry	0.071 (a)	0.024 (a)	0.095 (a)	0 (a)	0 (a)	0.083
Mild	0.095 (a)	0.119 (a)	0.214 (a)	0.262 (a)	0.286 (a)	0.113
Nostalgic	0.071 (a)	0.024 (a)	0.048 (a)	0 (a)	0.071 (a)	0.373
Polite	0.119 (a)	0.048 (a)	0.071 (a)	0.095 (a)	0.119 (a)	0.746
Peaceful	0.048 (a)	0.095 (a)	0.024 (a)	0.095 (a)	0.095 (a)	0.582
Pleasant	0.095 (ab)	0.119 (ab)	0.238 (b)	0.024 (a)	0.190 (ab)	0.036
Pleased	0.048 (ab)	0 (a)	0.167 (b)	0.024 (ab)	0.095 (ab)	0.012
Quiet	0.119 (a)	0.095 (a)	0.190 (a)	0.143 (a)	0.143 (a)	0.780
Satisfied	0.095 (a)	0.071 (a)	0.143 (a)	0.048 (a)	0.095 (a)	0.629
Secure	0.048 (a)	0.048 (a)	0.024 (a)	0.024 (a)	0.119 (a)	0.273
Steady	0.095 (a)	0.024 (a)	0.095 (a)	0.095 (a)	0.071 (a)	0.673
Tame	0.024 (a)	0.024 (a)	0.119 (a)	0.143 (a)	0.048 (a)	0.097
Tender	0.024 (a)	0 (a)	0 (a)	0.024 (a)	0.024 (a)	0.736
Understanding	0.071 (a)	0 (a)	0.095 (a)	0.024 (a)	0.024 (a)	0.199
Warm	0.071 (a)	0.024 (a)	0.143 (a)	0.048 (a)	0.048 (a)	0.187
Wild	0.119 (a)	0.048 (a)	0 (a)	0.095 (a)	0.143 (a)	0.112
Worried	0.167 (a)	0.071 (a)	0.167 (a)	0.167 (a)	0.119 (a)	0.634
Whole	0.119 (a)	0.024 (a)	0.024 (a)	0.024 (a)	0.119 (a)	0.104

[1]Proportions with different letters indicate a significant difference at $P < 0.05$.

Table 5. A contingency table of the proportions of selection for emotional attributes among the sweet-dominant brownie samples served on the five plates with different colors

	White	Light gray	Gray	Dark gray	Black	*P*-value
Active	0.143 (a)[1]	0.167 (a)	0.190 (a)	0.048 (a)	0.190 (a)	0.332
Adventurous	0.048 (a)	0.095 (a)	0.119 (a)	0.048 (a)	0.167 (a)	0.301
Affectionate	0.143 (a)	0.167 (a)	0.190 (a)	0.143 (a)	0.143 (a)	0.971
Aggressive	0 (a)	0 (a)	0.024 (a)	0.024 (a)	0 (a)	0.558
Bored	0.048 (a)	0.024 (a)	0 (a)	0.048 (a)	0.024 (a)	0.675
Calm	0.310 (a)	0.452 (a)	0.405 (a)	0.405 (a)	0.310 (a)	0.573
Daring	0.119 (a)	0 (a)	0.048 (a)	0.024 (a)	0.048 (a)	0.136
Disgusted	0 (a)	0 (a)	0.024 (a)	0.024 (a)	0.024 (a)	0.736
Eager	0.190 (a)	0.238 (a)	0.143 (a)	0.143 (a)	0.048 (a)	0.149
Energetic	0.286 (a)	0.167 (a)	0.071 (a)	0.143 (a)	0.190 (a)	0.160
Enthusiastic	0.190 (a)	0.286 (a)	0.238 (a)	0.214 (a)	0.214 (a)	0.884
Free	0.190 (a)	0.119 (a)	0.167 (a)	0.048 (a)	0.095 (a)	0.269
Friendly	0.310 (a)	0.452 (a)	0.333 (a)	0.310 (a)	0.310 (a)	0.554
Glad	0.357 (a)	0.333 (a)	0.405 (a)	0.238 (a)	0.333 (a)	0.608
Good	0.548 (a)	0.667 (a)	0.690 (a)	0.571 (a)	0.643 (a)	0.588
Good-natured	0.167 (a)	0.357 (a)	0.214 (a)	0.190 (a)	0.214 (a)	0.251
Guilty	0.095 (a)	0 (a)	0.095 (a)	0.048 (a)	0.024 (a)	0.213
Happy	0.429 (a)	0.500 (a)	0.619 (a)	0.524 (a)	0.476 (a)	0.520
Interested	0.310 (a)	0.405 (a)	0.357 (a)	0.262 (a)	0.238 (a)	0.485
Joyful	0.167 (a)	0.190 (a)	0.286 (a)	0.167 (a)	0.238 (a)	0.605
Loving	0.071 (a)	0.190 (a)	0.167 (a)	0.095 (a)	0.024 (a)	0.088
Merry	0.119 (a)	0.143 (a)	0.190 (a)	0.048 (a)	0.119 (a)	0.429
Mild	0.167 (a)	0.190 (a)	0.119 (a)	0.214 (a)	0.167 (a)	0.819
Nostalgic	0.214 (a)	0.071 (a)	0.238 (a)	0.238 (a)	0.167 (a)	0.283
Polite	0.143 (a)	0.119 (a)	0.190 (a)	0.190 (a)	0.143 (a)	0.851
Peaceful	0.167 (a)	0.238 (a)	0.238 (a)	0.238 (a)	0.167 (a)	0.811
Pleasant	0.452 (a)	0.690 (a)	0.667 (a)	0.548 (a)	0.524 (a)	0.154
Pleased	0.452 (a)	0.667 (a)	0.500 (a)	0.452 (a)	0.500 (a)	0.204
Quiet	0.048 (a)	0.071 (a)	0.119 (a)	0.071 (a)	0.048 (a)	0.663
Satisfied	0.548 (a)	0.571 (a)	0.595 (a)	0.500 (a)	0.500 (a)	0.858
Secure	0.048 (a)	0.167 (a)	0.119 (a)	0.071 (a)	0.048 (a)	0.265
Steady	0.024 (a)	0.071 (a)	0.071 (a)	0.095 (a)	0.095 (a)	0.710
Tame	0.095 (a)	0.024 (a)	0.024 (a)	0.071 (a)	0.095 (a)	0.451
Tender	0 (a)	0.143 (a)	0.119 (a)	0.024 (a)	0.048 (a)	0.042
Understanding	0.048 (a)	0.143 (a)	0.071 (a)	0.024 (a)	0.071 (a)	0.250
Warm	0.238 (a)	0.286 (a)	0.357 (a)	0.238 (a)	0.238 (a)	0.663
Wild	0 (a)	0 (a)	0 (a)	0 (a)	0 (a)	1.000
Worried	0 (a)	0 (a)	0.024 (a)	0 (a)	0.024 (a)	0.558
Whole	0.119 (a)	0.190 (a)	0.119 (a)	0.143 (a)	0.071 (a)	0.569

[1]Proportions with different letters indicate a significant difference at *P* < 0.05.
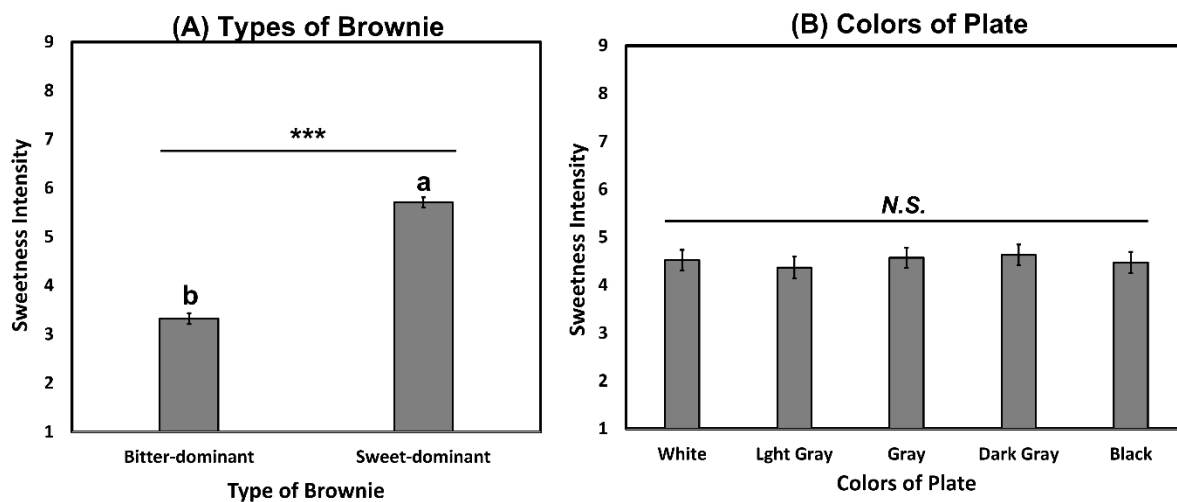
Figure 1. Effects of the types of brownie (A) and the colors of plate (B) in terms of sweetness intensity of brownie samples. *** represents a significant difference at $P < 0.001$. *N.S.* represents no significant difference at $P < 0.05$. Mean ratings with different letters represent a significant difference at $P < 0.05$.
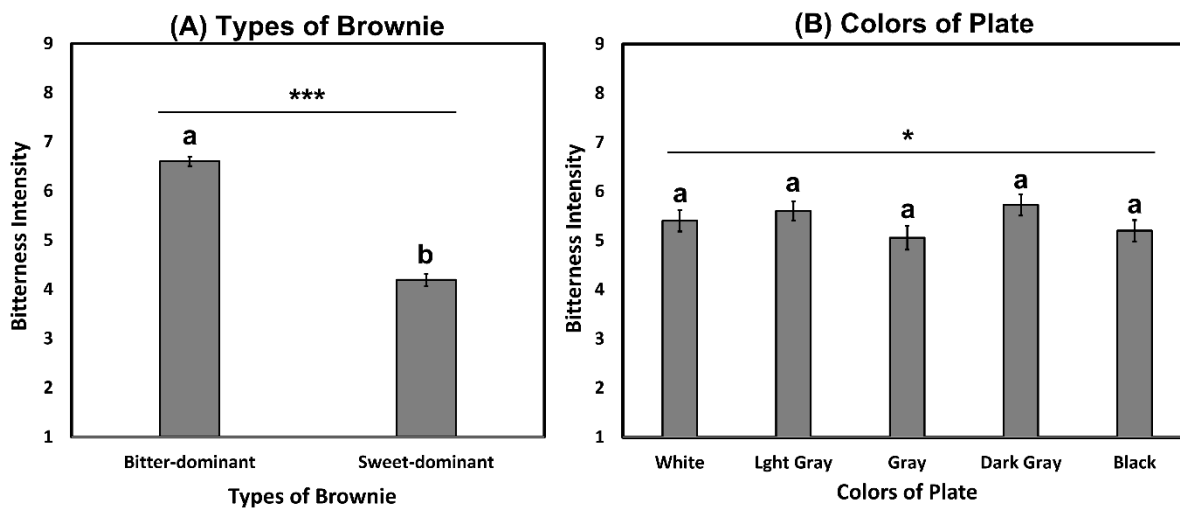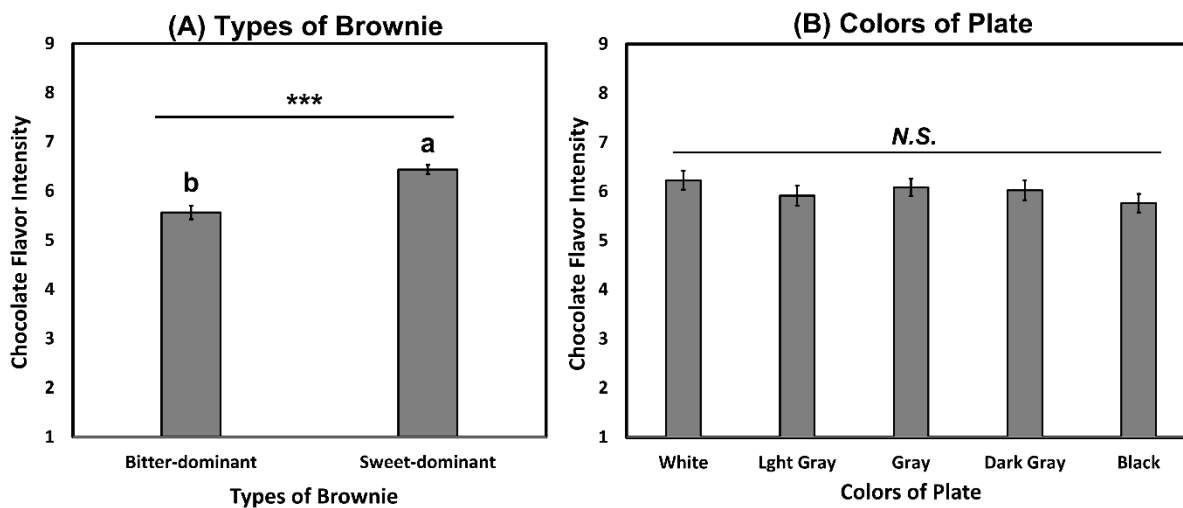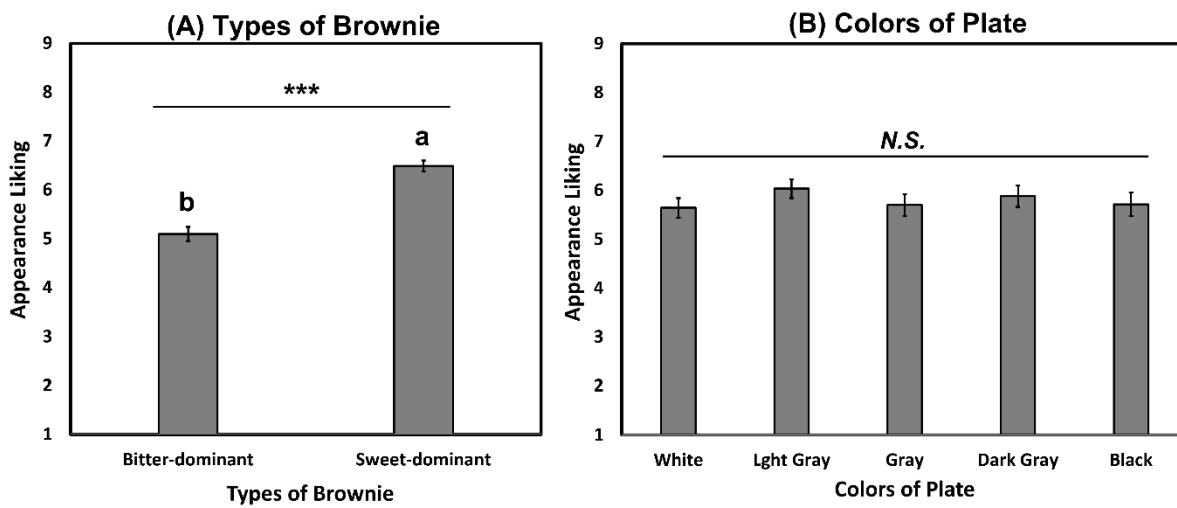
Effect of Plate Darkness on Food Perception

Figure 2. Effects of the types of brownie (A) and the colors of plate (B) in terms of bitterness intensity of brownie samples. * and *** represent a significant difference at $P < 0.05$ and $P < 0.001$, respectively. *N.S.* represents no significant difference at $P < 0.05$. Mean ratings with different letters represent a significant difference at $P < 0.05$.

Effect of Plate Darkness on Food Perception

Figure 3. Effects of the types of brownie (A) and the colors of plate (B) in terms of chocolate flavor intensity of brownie samples. *** represents a significant difference at $P < 0.001$. *N.S.* represents no significant difference at $P < 0.05$. Mean ratings with different letters represent a significant difference at $P < 0.05$.
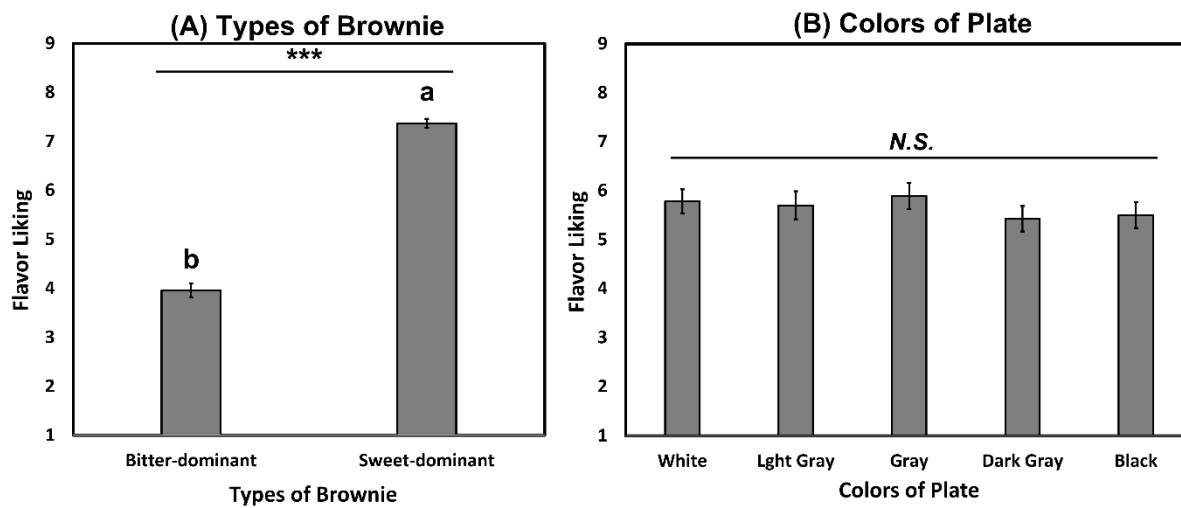
Effect of Plate Darkness on Food Perception

Figure 4. Effects of the types of brownie (A) and the colors of plate (B) in terms of appearance liking of brownie samples. *** represents a significant difference at $P < 0.001$. *N.S.* represents no significant difference at $P < 0.05$. Mean ratings with different letters represent a significant difference at $P < 0.05$.

Figure 5. Effects of the types of brownie (A) and the colors of plate (B) in terms of flavor liking of brownie samples. *** represents a significant difference at *P* < 0.001. *N.S.* represents no significant difference at *P* < 0.05. Mean ratings with different letters represent a significant difference at *P* < 0.05.

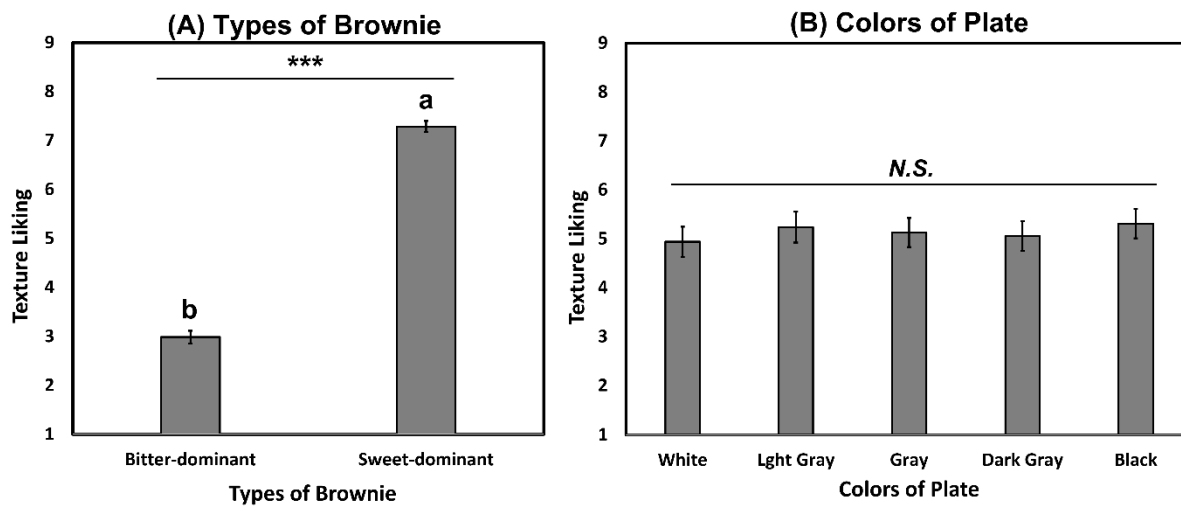Effect of Plate Darkness on Food Perception

Figure 6. Effects of the types of brownie (A) and the colors of plate (B) in terms of texture liking of brownie samples. *** represents a significant difference at $P < 0.001$. *N.S.* represents no significant difference at $P < 0.05$. Mean ratings with different letters represent a significant difference at $P < 0.05$.

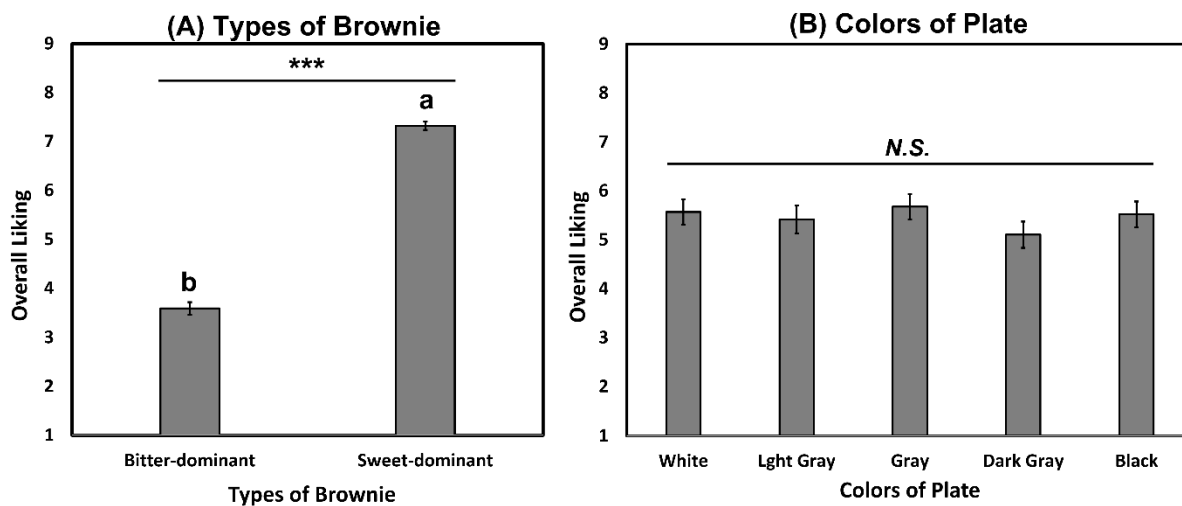Effect of Plate Darkness on Food Perception

Figure 7. Effects of the types of brownie (A) and the colors of plate (B) in terms of overall liking of brownie samples. *** represents a significant difference at *P* < 0.001. *N.S.* represents no significant difference at *P* < 0.05. Mean ratings with different letters represent a significant difference at *P* < 0.05.

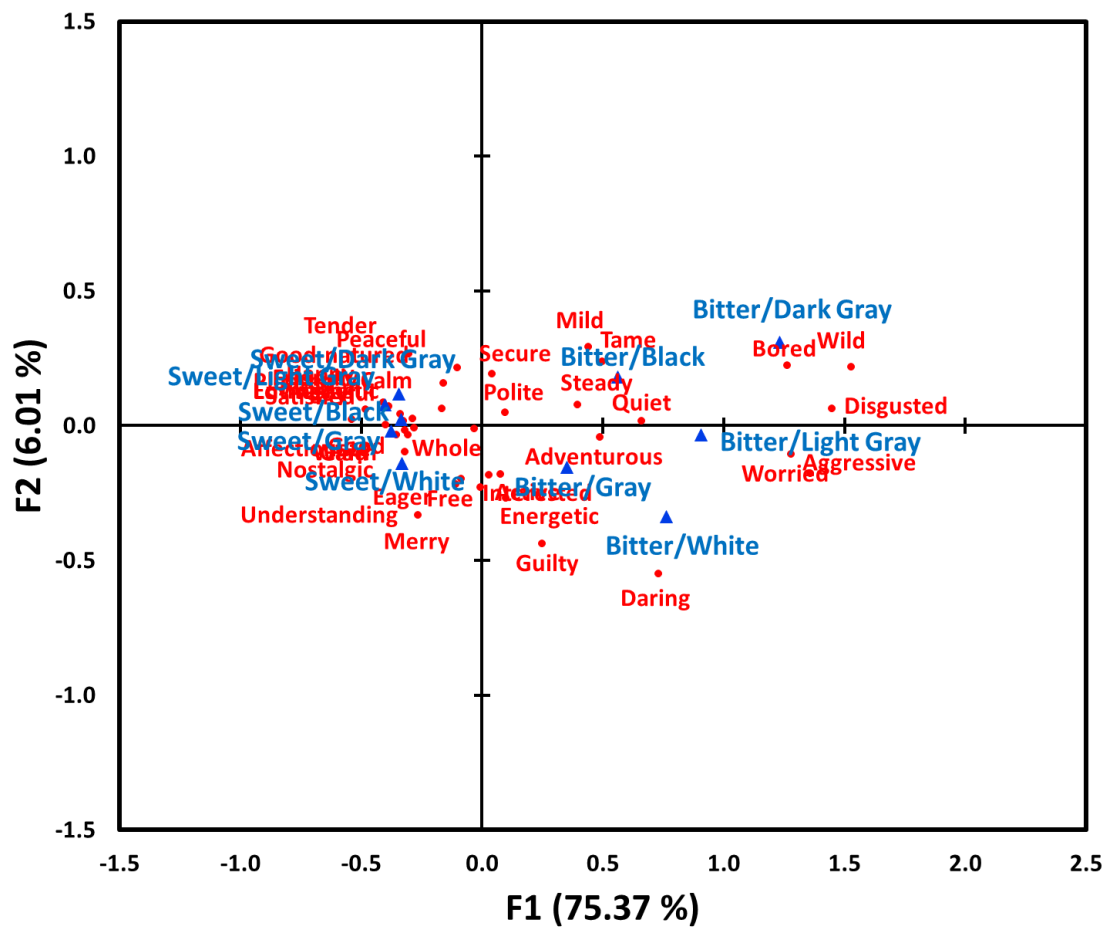Effect of Plate Darkness on Food Perception

Figure 8. A biplot of a correspondence analysis based on associations between 10 test samples and 39 emotional attributes