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Color of hot soup modulates postprandial satiety, thermal sensation, and body temperature in young women

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ABSTRACT

The color of food is known to modulate not only consumers' motivation to eat, but also thermal perception. Here we investigated whether the colors of hot soup can influence thermal sensations and body temperature, in addition to the food acceptability and appetite. Twelve young female participants consumed commercial white potage soup, modified to yellow or blue by adding food dyes, at 9 a.m. on 3 separated days. During the test, visual impression (willingness to eat, palatability, comfort, warmth, and anxiety) and thermal sensations were self-reported using visual analog scales. Core (intra-aural) and peripheral (toe) temperatures were continuously recorded 10 min before and 60 min after ingestion. Blue soup significantly decreased willingness to eat, palatability, comfort, and warmth ratings, and significantly increased anxiety feelings compared to the white and yellow soups. After ingestion, the blue soup showed significantly smaller satiety ratings and the tendency of lower thermal sensation scores of the whole body compared to the white and yellow soups. Moreover, a significantly greater increase in toe temperature was found with the yellow soup than the white or blue soup. In conclusion, this study provides new evidence that the colors of hot food may modulate postprandial satiety, thermal sensations and peripheral temperature. Such effects of color may be useful for dietary strategies for individuals who need to control their appetite.

1. Introduction

The appearance, particularly the color, of food items is an important source of information for consumers to judge the safety, readiness for eating, and palatability before consumption (Hutchings, 1999; Eertmans, Baeyens, & Van den Bergh, 2001). In addition to basic palatability, food color affects the consumers' ability to correctly identify flavor, which dominates other information sources (Garber, Hyatt, & Starr, 2000). Since food color influences taste thresholds, food preference, pleasantness, and acceptability, it plays a key role in food choice and consumption (Spence, 2015).

Research has shown that the impression and acceptability of certain food items change when they are placed under different colors of lighting. Consumers' willingness to eat and the liking of appearance for apples and bell peppers were found to be higher when they were presented under yellow or white lighting and lower under blue lighting (Yang, Cho, & Seo, 2016; Hasenbeck et al., 2014). Similarly, consumers' hedonic impression of the appearance of a set meal (omelets and pancakes) decreased when it was served under blue compared with yellow or white lighting (Cho et al., 2015).

The psychological effects of food color also relate eating behavior. Previous studies examining appetite and food intake in relation to color demonstrated that, compared with blue lighting, yellow lighting increased consumers' appetite (Suk, Park, & Kim, 2012; Yang et al., 2016) and, although only in men, food intake (Cho et al., 2015). Concerning a foodstuff having naturally different colors, a recent study reported that yellow potato salad was perceived as more appetizing and more likely to be chosen by consumers than blue potato salad (Paakki, Sandell, & Hopia, 2016). These studies showed similar results, in that the colors yellow and

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white tend to enhance consumers' motivation to eat, acceptability, appetite, and food intake, whereas blue tends to decrease them. Since these findings may be helpful for managing overeating and anorexia to control food intake, it would be interesting to investigate these effects using soups, a common starter of a meal, as the study sample.

Color is also known to influence the perception of the temperature of food. In general, red and yellow are categorized as warm colors, and blue and green as cold colors. A previous study demonstrated that sniffing red- and green-colored water induced warming and cooling sensations, respectively (Michael & Rolhion, 2008). A cold beverage item was evaluated as more thirst-quenching when presented in a blue glass than in a green, yellow, or red glass (Guéguen, 2003), and a hot beverage was perceived as the warmest when served in a red cup, followed by yellow, green, and blue cups (Guéguen & Jacob, 2014). Thus, the color (warm or cold) of a beverage and its container has been shown to affect the perception of the temperature of the beverage.

In regard to the effect of color on physiological responses, viewing or exposure to different colors is known to modulate body temperature in humans. After viewing a piece of red colored paper, a greater increase in peripheral skin temperatures was shown; while decreased peripheral temperatures were observed after viewing blue (Shen, Tone, & Asayama, 1999). As ambient colors, compared to yellow colored light, white (similar to daylight) colored fluorescent lamps suppressed the nocturnal fall of core temperature (Morita & Tokura, 1996) and enhanced cardiac autonomic nerve activity even during nighttime (Mukae & Sato, 1992). However, the interesting topic of whether the color of food also influences the postprandial thermal sensation and body temperature has yet to be fully investigated.

Accordingly, the purpose of this study was to determine whether colors of hot soup can affect consumers' acceptability, motivation to eat, postprandial satiety, and thermal responses, using three differently (warm-, cold-, and white-) colored hot soups identical in energy content and flavor.

2. Materials and methods

2.1. Ethics statement

The study protocol was reviewed and approved by the School of Human Science and Environment Research Ethics Committee of the University of Hyogo (No.134, March 4, 2016), and was in accordance with the Declaration of Helsinki. The experimental procedure was carefully explained to all participants and all gave their written informed consent to participate in this study.

2.2. Participants

We recruited twelve female volunteers (mean ± standard errors: age, 22.0 ± 0.3 years; height, 160.9 ± 1.0 cm; body mass, 50.6 ± 1.8 kg; body mass index, 19.5 ± 0.7 kg/m^2; percentage of body fat, 24.6 ± 1.5%; systolic blood pressure, 100 ± 2 mmHg; diastolic blood pressure, 63 ± 2 mmHg) from our campus. To determine sample size, we have taken an estimated effect size of 0.20 according to the data regarding female body temperature changes following hot soup ingestion (Takagi et al., 2013). With an effect size (0.20), α error probability (0.05), power (0.8), numerator of *df* (14) and number of groups (3), 12 participants were required. The calculation was made by using a statistical power analysis program, G*power (Faul, Erdfelder, Lang, & Buchner, 2007). All participants regularly consumed breakfast, and were non-smokers, non-obese, and not suffering from medical symptoms or had a medical history of diseases that related to olfactory and visual impairments, appetite, and energy metabolism.

2.3. Test meals

Based on conventional associations between warm *vs*. cool colors, we prepared potage soups with yellow (warm), blue (cold), and white (achromatic) colors (Fig. 1). All soups were made by the same commercial food product (potato potage soup, Knorr Foods Co., Inc., Kanagawa, Japan, energy, 69 kcal; protein, 1.4 g; fat, 2.2 g; carbohydrates, 11.0 g; Na, 500 mg).

Minimal amounts of gardenia yellow (80 mg) and gardenia blue pigments (50 mg) were added to the white powdered soup product to create yellow- and blue-colored soup powders, respectively. All soup powders were tested for bacterial contamination and stored in sealed aluminum pouches. Each soup powder was dissolved in 150 mL of boiling water in a white ceramic soup cup with a cover and kept at 65 °C until ingestion. Participants consumed these three types of soup in a random order at the same time on separate days, within a 1- to 18-day interval. The eating time was set at 5 min.

Table 1 shows the characteristics of the soup samples. Taste (sweetness, saltiness, and umami) and aroma were evaluated by six expert sensory panels, each of whom rated the samples presented in a random order on a Likert scale from 1 (very weak) to 7 (very intense). Viscosity was measured using a Brookfield-type rotary viscometer (Brookfield Engineering Laboratories, Inc., Stoughton, MA, USA) with a No. 1 rotor at 50 rpm at 65 °C. The taste, aroma, and viscosity data showed no significant differences among the samples. The color of the samples was evaluated in terms of uniform color space parameters, namely L* (lightness), a* (+a*, red direction; −a*, green direction), and b* (+b*, yellow direction; −b*, blue direction), determined using a spectrophotometer (SE6000, Nippon Denshoku Industries Co., LTD, Tokyo, Japan).

2.4. Experimental procedure

Participants were asked to maintain their usual lifestyle and body mass at least one month before the test, and were tested on 3 separate days in a randomized order at 9 a.m. The day before the test, the consumption of coffee, tea, spicy foods, and high-fat foods was prohibited, and no sports activities were permitted that evening. On the morning of the test, participants came to our laboratory at 8 a.m. after an overnight fast beginning at 10 p.m. the previous night. After participants changed into examination clothes, anthropometric data was measured using a bioelectrical impedance analyzer (InBody520, Biospace Co., Soul, Korea), and blood pressure was measured twice using an electrical sphygmomanometer (HEM-907, OMRON Co., Kyoto, Japan) on the first visit of the test.

Then, participants were prepared for body temperature measurement and rested for at least 15 min in a sitting-up, 45° inclined position in a temperature controlled (25–26 °C) room. After the resting period, the intra-aural and toe temperatures, using devices with high-sensitivity thermosensors (Nikkiso-thermo Co., Ltd., Tokyo, Japan), were continuously recorded for 20 min before and 60 min after ingestion. Each bed was separated by a portable partition. During the measurement, participants remained seated quietly reading books.

To assess visual impression (willingness to eat, palatability, warmth, comfort, and sense of anxiety), subjective appetite (hunger and satiety) and thermal sensations (whole body and toe), each participant marked their feelings on visual analog scales (VAS). The VAS were 100 mm long horizontal lines with words expressing the most negative (not at all) to most positive (extremely) rating anchored at each end. The participants were asked to make a univocal mark on the horizontal line that corresponded to their