Research Article

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Color and illuminance level of lighting can modulate willingness to eat bell peppers

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Abstract

BACKGROUND: Food products are often encountered under colored lighting, particularly in restaurants and retail stores. However, relatively little attention has been paid to whether the color of ambient lighting can affect consumers' motivation for consumption. This study aimed to determine whether color (Experiment 1) and illuminance level (Experiment 2) of lighting can influence consumers' liking of appearance and their willingness to eat bell peppers.

RESULTS: For red, green, and yellow bell peppers, yellow and blue lighting conditions consistently increased participants' liking of appearance the most and the least, respectively. Participants' willingness to consume bell peppers increased the most under yellow lighting and the least under blue lighting. In addition, a dark condition (i.e. low level of lighting illuminance) decreased liking of appearance and willingness to eat the bell peppers compared to a bright condition (i.e. high level of lighting illuminance).

CONCLUSION: Our findings demonstrate that lighting color and illuminance level can influence consumers' hedonic impression and likelihood to consume bell peppers. Furthermore, the influences of color and illuminance level of lighting appear to be dependent on the surface color of bell peppers.

Keywords: lighting color; lighting illuminance; willingness to eat; liking of appearance; LED lighting

INTRODUCTION

Integration of multi-sensory cues is fundamental in human perception and acceptance of food. Visual cues, such as color and texture, are thought to be the most critical determinant of food perception and selection.[1,2] More specifically, color cues are often indicative of food quality,[3] and appear to modulate consumers' willingness to pay.[4] For example, Alfnes *et al.*[4] found that consumers were significantly more willing to pay for salmon fillets with typical and above typical redness compared to fillets with below typical redness. Food color cues have also been reported to alter chemosensory perception (for reviews see Delwiche[5] and Spence *et al.*[6]). For instance, Morrot *et al.*[7] lexically analyzed the tasting comments of wine experts and found white wines colored red were described as red wines.

The color of foods can vary as a function of many food-dependent factors such as cultivar, cultivation practices, maturity and processing.[8] Extrinsic factors such as the shape and color of dishes and glasses used during consumption[9–11] and the source of lighting used for food display have also been shown to alter the color of food.[8,12,13] Barbut[12] demonstrated that consumer acceptance of fresh meat color varied according to the lighting source used for display (i.e. incandescent, fluorescent and metal halide). Consumers reported significantly higher acceptance for the color of beef steaks when they were presented under incandescent light compared to fluorescent and metal halide light. Similarly, red and green bell peppers were acceptable under incandescent light significantly more than under fluorescent and/or metal halide lights.[8]

Food products are often encountered under different illuminants and/or colored lighting, particularly in restaurants and retail stores; thus, food product appearance may be positively or negatively influenced depending on the lighting conditions. Still, relatively little attention has been paid to whether the color of ambient lighting can influence food acceptance and intake. Wilson and Gregson[14] reported the influence of colored lighting on perception of citric acid solution. In a recent study conducted by Suk *et al.*,[15] participants were provided with various food stimuli (e.g. green salads, blueberry cake, sweets and beverages, Korean roll, and mixed sweets) under colored light-emitting diode (LED) lighting. Using lighting palette software, participants were asked to freely select the best and worst color combinations of lighting and

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food stimuli. Participants selected yellow lighting as the best match with the food stimuli more frequently, whereas they selected red and blue lighting as the worst match more often. However, in another study using four different colors of ambient fluorescent lamps,[16] red and blue lighting increased overall liking of wine (a dry Riesling) compared to green and white lighting.[16] Further, participants were willing to pay more for the wine when the ambient lighting was red or blue than when it was green or white.

In addition to color cue, the illuminance level of lighting appears to influence consumers' eating and shopping behaviors.[17–21] The majority of the previous studies have highlighted the impact of lighting illuminance on consumption rate, amount consumed, and time consumed.[19] Although the lighting illuminance-induced eating and shopping behaviors have been inconsistent across earlier studies, it has been found that warm, soft, or dim lighting, in comparison to bright or harsh lighting, leads patrons to spend more time in their eating environment, as well as to order additional food.[20,21] Yet, as little is known about the effect of lighting illuminance on consumers' food perception, this study attempted to investigate whether consumers' perception and appetite can vary as a function of lighting illuminance levels.

With previous research findings in mind, the current study aimed to determine whether color (Experiment 1) and illuminance level (Experiment 2) of ambient lighting could alter consumers' willingness to eat the bell peppers, as well as their hedonic impression of appearance. More specifically, given that (1) lighting color can alter a surface color of food and (2) the surface color of food appears to affect consumers' food acceptance and intake, Experiment 1 was designed to determine whether five different colors of lighting could modulate consumers' liking of appearance and their willingness to eat the food (i.e. bell peppers). In addition, based on insight that lighting illuminance affects eating behavior and food intake,[18–21] Experiment 2 aimed to determine whether three levels of lighting illuminance (e.g. dark, medium and bright) can modulate consumers' acceptance of appearance and their willingness to eat the food (i.e. bell peppers). While previous studies conducted by Barbut[8,12,13] have focused on the effects of lighting source (i.e. incandescent, fluorescent and metal halide), this study attempted to answer the question as to whether colors (i.e. white, yellow, green, red, and blue) and illuminance levels (i.e. dark, medium and bright) of LED lighting can influence consumers' liking of appearance and their willingness to eat the food. An additional objective was to determine whether the influences of lighting color and/or illuminance level can vary as a function of the surface color of food. To minimize potential interactions between color and size/shape in visual perception,[22,23] we used three colored bell peppers (e.g. green, yellow and red) that were nearly identical in shape. This allowed us to emphasize the interaction between the colors of lighting and food.

Finally, because this study was designed to focus on how visual cues influence consumers' liking of appearance and their willingness to eat the bell peppers, photographic slides of bell peppers were used as visual stimuli, instead of real bell peppers. Selection of visual slides as stimuli was based on previous research findings that photographs can serve as a convenient and reliable alternative for the use of real foods in studies measuring participants' preference.[24]

EXPERIMENT 1

This study was conducted according to the Declaration of Helsinki for studies on human subjects. The protocol was approved by the University Institutional Review Board of the University of Arkansas (Fayetteville, AR).

Methods

Participants

Fifty-seven healthy volunteers (49 females and eight males) with an age range between 19 and 76 years [mean age ± standard deviation (SD) = 29 ± 15 years] took part in this experiment. All participants confirmed they had no clinical history of major diseases. In addition, all participants reported that they had no impairment in olfactory and gustatory function and normal or corrected-to-normal vision. Participants' color blindness was screened using the Ishihara color test.[25] Participants were asked to rate their hunger status and overall liking of bell peppers on two nine-point Likert scales (1 = extremely hungry/dislike extremely to 9 = extremely full/like extremely), respectively. Overall, participants reported that they were slightly hungry (mean ± SD = 4.3 ± 1.6) and moderately liked bell peppers (mean ± SD = 6.8 ± 1.6). The experimental procedure was thoroughly explained to all participants and an informed written consent was obtained.

Stimuli and presentation

To present identical stimuli across participants, photographic slides of bell peppers (*Capsicum annuum*) were used as visual stimuli. The visual slides included each picture of green, red or yellow bell peppers taken under white, yellow, green, blue and white colored-LED lighting (Mutli-Color LED Lightbulb; ThinkGeek, Inc., Fairfax, VA, USA), respectively. The illuminance levels of five different colored-lightings were controlled, ranging between 9.0 and 13.5 lux. As illustrated in Fig. 1, each picture (640 × 480 pixels) represented a whole bell pepper and a cross-section placed on a white plastic plate [Hunter L (whiteness) = 83.5 ± 0.1, a (redness/greenness) = −1.9 ± 0.3, and b (yellowness/blueness) = −2.8 ± 0.2] under each of the five colored-lighting conditions. Table 1 shows the color characteristics (i.e. Hunter L, a, and b values), measured using a colorimeter (ColorFlex; Hunter Association Laboratory, Reston, VA, USA), of three bell peppers. Additionally, for easier conceptualization of color perception, chroma and hue angle values were calculated as follows:[26,27] chroma $= (a^2 + b^2)^{1/2}$; hue angle $= \tan^{-1}(b/a)$. Chroma indicates color saturation;[27] for example, higher chroma values represent more vividness than lower ones. Regarding the hue angle, angles of 0°, 90°, 180°, and 270° represent red, yellow, green and blue colors, respectively.[27]

Procedure

Participants were seated in individual booths lit with standard fluorescent (i.e. white) lighting (mean ± SD = 646 ± 16 lux) at ambient temperature (20°C). Each participant was presented with a total of 15 visual slides (i.e. five lighting colors by three bell peppers colors) on a LED computer monitor (34 cm × 27 cm) with a screen mode of 1280 × 1024 pixels via Microsoft PowerPoint 2010 in the following order: green, red and yellow bell peppers. For each bell pepper color, five lighting colors were randomized. The video card used in this study was Intel® Extreme Graphics 2. Each slide was presented for 15 s and the time interval between slides was approximately 10 s. During the interval, a white background slide was presented.

While watching each photographic slide, participants were asked to rate their willingness to eat the illustrated bell peppers on a nine-point Likert scale ranging from 1 (extremely unwilling) to 9

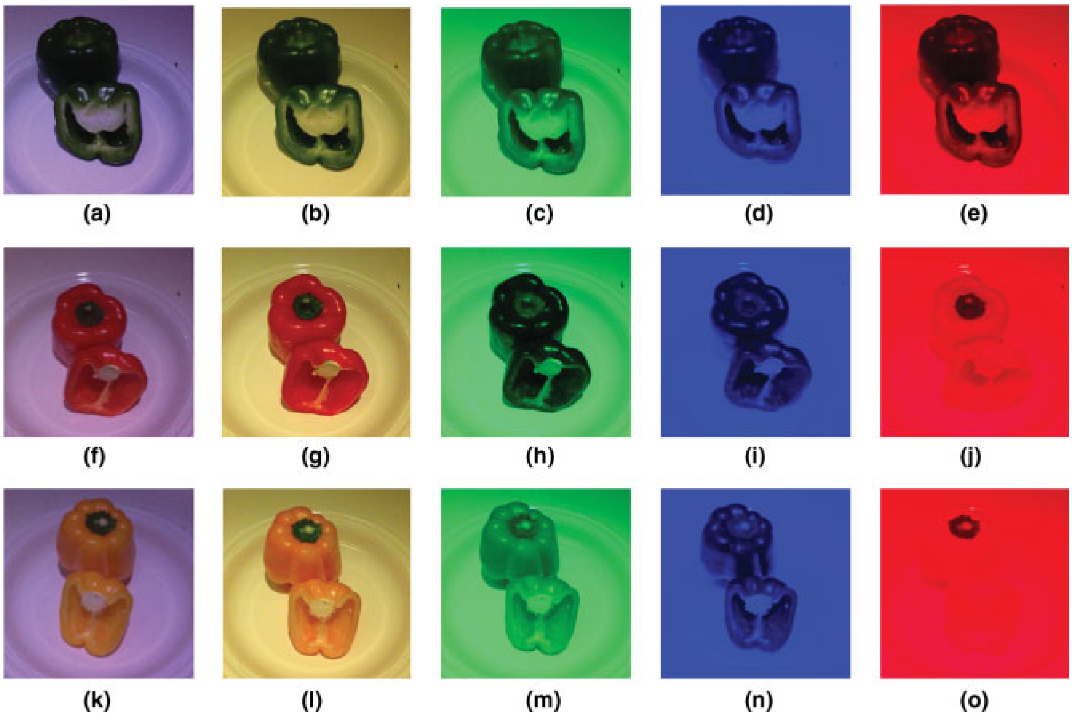

Figure 1. An example of the visual slides used in Experiment 1. The visual slides included each picture of green (a to e), red (f to j), or yellow (k to o) bell peppers taken under white, yellow, green, blue and red colored-LED lighting, respectively.

Table 1. Mean scores (±standard deviation) in the color characteristics of bell peppers used in this study

Bell pepper color	Hunter Lab values			Chroma	Hue angle (°)
	L (whiteness)	*a* (redness)	*b* (yellowness)		
Green	41.2 (±4.3)	−9.5 (±0.8)	23.1 (±5.9)	25.0 (±5.7)	113.1 (±3.7)
Red	36.2 (±2.0)	36.8 (±2.0)	22.4 (±2.1)	43.1 (±2.7)	31.3 (±1.5)
Yellow	60.0 (±0.8)	15.2 (±1.4)	61.4 (±3.6)	63.2 (±3.5)	76.1 (±1.5)

Chroma $= (a^2 + b^2)^{1/2}$.
Hue angle $= \tan^{-1}(b/a)$, where 0° = red-purple, 90° = yellow, 180° = green, and 270° = blue.

(extremely willing) on paper. Similarly, participants reported their overall liking of the appearance of the bell peppers on a nine-point Likert scale ranging from 1 (dislike extremely) to 9 (like extremely).

Data analysis

Data analysis was performed by means of SPSS 20.0 (IBM SPSS Inc., Chicago, IL, USA). To determine whether lighting color can modulate consumers' willingness to eat bell peppers and their hedonic impression of the appearance, data were analyzed by using repeated measures analyses of variance (RM-ANOVAs). If the Sphericity assumption was violated via the Mauchly Sphericity test, the degrees of freedom were adjusted by using 'Greenhouse–Geisser' correction. If a significant difference of means was indicated by RM-ANOVAs, post hoc comparisons between independent variables were performed using Bonferroni *t*-tests. The alpha level was 0.05.

Results

Influences of bell pepper and lighting colors on liking of appearance

There was a significant interaction between bell pepper and lighting colors in liking of appearance [Greenhouse–Geisser correction: F (5.77, 323.13) = 21.88, $P < 0.001$]. For green bell peppers, consumers' liking of appearance was significantly higher under yellow, green and white lighting than under blue lighting (for all comparisons, $P < 0.001$) as shown in Fig. 2a. For red bell peppers, appearance liking was significantly highest and lowest under yellow (for all comparisons, $P < 0.001$) and blue (for all comparisons, $P < 0.05$) lightings, respectively. Lastly, for yellow bell peppers, liking of appearance was significantly higher under yellow and green lighting than under blue and red lightings (for all comparisons, $P < 0.001$), respectively.

Influences of bell pepper and lighting colors on willingness to eat

A significant interaction between bell pepper colors and lighting color was observed [Greenhouse–Geisser correction: F (5.46, 305.51) = 20.85, $P < 0.001$]. Figure 2b demonstrates that participants were willing to eat green bell peppers under yellow and green lighting significantly more than under red and blue lighting (for all comparisons, $P < 0.05$). Participants' willingness to eat was significantly lowest under blue lighting (for all comparisons, at least $P < 0.001$). For red bell peppers, willingness to eat was significantly highest and lowest under

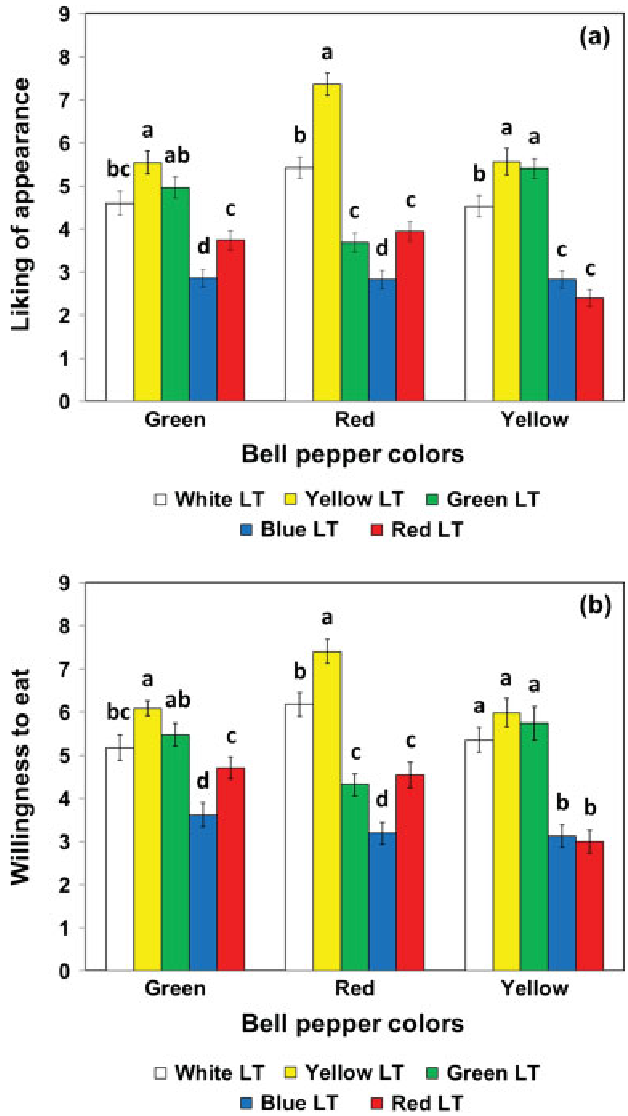

Figure 2. Mean differences in liking of appearance (a) and willingness to eat bell peppers (b) as a function of the color of lighting: white, yellow, green, blue, and red lights (LT). Means with different letters were significantly different from each other ($P < 0.05$). The error bars represent the standard errors of the means.

yellow (for all comparisons, at least $P < 0.001$) and blue lighting (for all comparisons, $P < 0.001$), respectively. Lastly, for yellow bell peppers, willingness to eat was significantly lower under red and blue lighting than under white, yellow, and green lighting (for all comparisons, $P < 0.001$); There was no significant difference between white, yellow, and green lighting conditions in willingness to eat (for all comparisons, $P > 0.05$).

Discussion of Experiment 1

Our findings demonstrate that lighting colors can alter consumers' willingness to eat bell peppers, as well as their overall liking of appearance. Overall, participants liked (or disliked) the appearance of bell peppers under yellow (or blue) lighting the most (Fig. 2a). Similarly, participants' willingness to eat bell peppers was highest and lowest under yellow and blue lighting, respectively (Fig. 2b). These results are in accordance with previous findings that orange and yellow lighting stimulate appetitive feeling, whereas red,

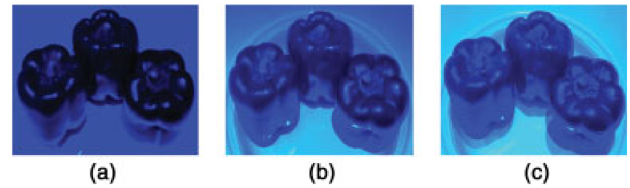

Figure 3. An example of the visual slides used in Experiment 2. The visual slides included each picture of bell peppers taken under yellow, blue or white colored-LED lighting in relation to three levels of lighting illuminance: low (a), medium (b), and high (c) illuminance levels.

green and blue lighting reduce appetite.[15] As shown in Fig. 1, blue lighting distorts the original surface color of bell peppers, which may negatively affect participants' visual ability to identify the food stimuli. In contrast, white and yellow lighting conditions may provide visual clarity for the surface color of bell peppers, which may facilitate participants' identification. In turn, this may lead participants to like the appearance of bell peppers under white and yellow lighting conditions more. Subsequently, higher liking of appearance can result in higher willingness to eat the bell peppers. Indeed, appearance acceptance and consumption likelihood showed a high correlation coefficient ($r_{855} = 0.84$, $P < 0.001$) in this study.

It should be noted that we obtained significant interactions between bell pepper and lighting colors for both parameters (i.e. liking of appearance and willingness to eat) under investigation. The most distinct interaction was observed between green lighting and red bell peppers. For green and yellow bell peppers, participants showed significantly greater willingness to eat under green lighting than under red and blue lightings. However, for red bell peppers, the green lighting decreased participants' willingness to eat, as seen in Fig. 2. Given the fact that red and green colors are a complementary, it can be thought that the complementary relationship between the colors of lighting and bell peppers decreased not only liking of appearance, but also willingness to eat red bell peppers (see Fig. 1h). Our results are, to some extent, consistent with previous findings.[15] Suk *et al.*[15] demonstrated that for red (or green) colored sweets and beverages, 50% of participants selected green (or red) out of six lighting colors (e.g. D65, red, orange, yellow, green, blue and purple) as the least appetitive color of lighting. However, in our study, the red lighting appears not to decrease participants' willingness to eat green bell peppers, although both colors have a complementary relationship. The plausible explanation for the lack of significance can be found in Fig. 1. In contrast to the red bell peppers under green lighting (Fig. 1h), green bell peppers under red lighting (Fig. 1e) still have their original color. Namely, green lighting can be reflected more from bell peppers with a red surface, whereas red lighting can be relatively more absorbed by bell peppers with a green surface. In addition, it is interesting to note that red lighting reduced ratings of willingness to eat for yellow bell peppers. As seen in Fig. 1, red lighting is reflected from the yellow surface (Fig. 1o) more than from the green (Fig. 1e) and red (Fgi. 1j) surfaces of bell peppers, which distorted the shape and color of the yellow bell peppers.

EXPERIMENT 2

Experiment 2 was designed to determine whether illuminance level of colored lighting can influence consumers' willingness to eat the bell peppers, as well as their liking of appearance.

Table 2. Three levels of lighting illuminance at each lighting color

Levels of lighting illuminance (units)	Lighting colors		
	Blue	Yellow	White
Low (lux)	9.0	12.2	12.2
Medium (lux)	37.0	48.5	49.9
High (lux)	132.0	174.0	175.4

Methods

Participants

Fifty-one healthy volunteers (27 females and 24 males) with an age range between 25 and 80 years (mean age ± SD = 52 ± 17 years) participated in this experiment. To minimize a potential learning effect, the participants from Experiment 1 were not allowed to participate in Experiment 2. All participants confirmed they had no clinical history of major diseases. All participants also reported they had no impairments in olfactory and gustatory functions and normal or corrected-to-normal vision. Using the Ishihara color test,[25] participants' color blindness was screened. The experimental procedure was thoroughly explained to all participants and an informed written consent was obtained. Participants were asked to rate their overall liking of bell pepper and hunger status on two nine-point Likert scales (1 = dislike extremely/extremely hungry to 9 = like extremely/extremely full), respectively. Participants reported they were neither hungry nor full (mean ± SD = 5.0 ± 1.3) and they slightly liked bell peppers (mean ± SD = 6.1 ± 2.2). The experimental procedure was thoroughly explained to all participants and an informed written consent was obtained.

Stimuli and presentation

As in Experiment 1, photographic slides of bell peppers were used as visual stimuli. The visual slides included each picture of bell peppers taken under yellow, blue or white colored-LED lighting in relation to three levels of illuminance: low (dark), medium and high (bright) levels. Unlike in Experiment 1, three colored whole bell peppers (i.e. green, red and yellow) were placed adjacent to each other on a white plate. Each picture (640 × 480 pixels) represented the bell peppers placed on a white plate under colored lighting with one of three illuminance levels (Fig. 3). Table 2 presents information on three levels of illuminance in each lighting color. Each picture was presented with a three-digit code.

Procedure

Participants were seated in individual booths lit with standard fluorescent lighting (mean ± SD = 646 ± 16 lux) at ambient temperature (20 °C). For all participants, a total of nine visual slides (i.e. three illuminance levels by three lighting colors) were presented on a LED computer monitor (34 cm × 27 cm) with a screen mode of 1280 × 1024 pixels via Microsoft PowerPoint 2010 in the following order: blue, yellow and white lighting colors. Participants could easily identify the bell peppers under white lighting, which results in an expectation-induced bias in their ratings for the following stimuli.[11,28] Therefore, the slide of bell peppers under blue lighting (i.e. less recognizable condition) was followed by those under yellow and white lightings. For each lighting color, three illuminance levels were randomized. The video card used in this study was Intel® Extreme Graphics 2. Each slide was presented for 15 s and the time interval between slides was approximately 10 s. During the 10 s interval, a white background slide was presented.

While watching each photographic slide, participants were instructed to rate their willingness to eat the bell peppers shown in the slide on a nine-point scale ranging between 1 (extremely unwilling) and 9 (extremely willing). They were also asked to rate liking of overall appearance of the bell peppers shown in the slide on a nine-point scale ranging between 1 (dislike extremely) to 9 (like extremely).

Data analysis

Data analysis was performed by means of SPSS 20.0 (IBM SPSS Inc., Chicago, IL, USA). To determine whether illuminance level of lighting can modulate consumers' willingness to eat the bell peppers, as well as their liking of appearance, data were analyzed by using repeated measures analyses of variance (RM-ANOVAs). If the Sphericity assumption was violated via the Mauchly Sphericity test, the degrees of freedom were adjusted by using 'Greenhouse–Geisser' correction. If a significant difference of means was indicated by RM-ANOVAs, post hoc comparisons between independent variables were performed using Bonferroni *t*-tests. The alpha level was 0.05.

Results

Influences of lighting color and illuminance on liking of appearance

Figure 4a shows a significant interaction between lighting color and illuminance level in liking of appearance [Greenhouse–Geisser correction: $F(3.27, 143.71) = 7.14$, $P < 0.001$]. For yellow lighting, participants liked appearance of bell peppers at high illuminance level significantly more than at low ($P < 0.001$) and medium ($P < 0.001$) illuminance levels, respectively. For white lighting, the reported liking of appearance was significantly smallest at low level (dark) of lighting illuminance (for all comparisons, $P < 0.001$). For blue lighting, participants liked the appearance of bell peppers at high illuminance level significantly more than at low illuminance level ($P = 0.001$). However, the liking of appearance was not significantly different at medium and high levels of lighting illuminance (for white color, $P = 0.06$; for blue color, $P = 0.17$).

Influences of lighting color and illuminance on willingness to eat

As shown in Fig. 4b, there was a significant interaction between lighting color and illuminance level in consumers' willingness to eat bell peppers [Greenhouse–Geisser correction: $F(3.21, 141.13) = 7.19$, $P < 0.001$]. For white lighting, willingness to eat was significantly higher at medium level of illuminance than at low (dark, $P < 0.001$) and high (bright, $P = 0.02$) levels of illuminance. For yellow lighting, willingness to eat was significantly greater at high level than at medium ($P = 0.01$) and low ($P = 0.001$) levels of lighting illuminance. Similarly, for blue lighting conditions, willingness to eat bell peppers was significantly greater at high level than at low level of lighting illuminance ($P = 0.03$).

Discussion of Experiment 2

Our results showed that illuminance level of lighting can modulate not only liking of appearance but also willingness to eat bell peppers. Overall, compared to low illuminance level (i.e. dark

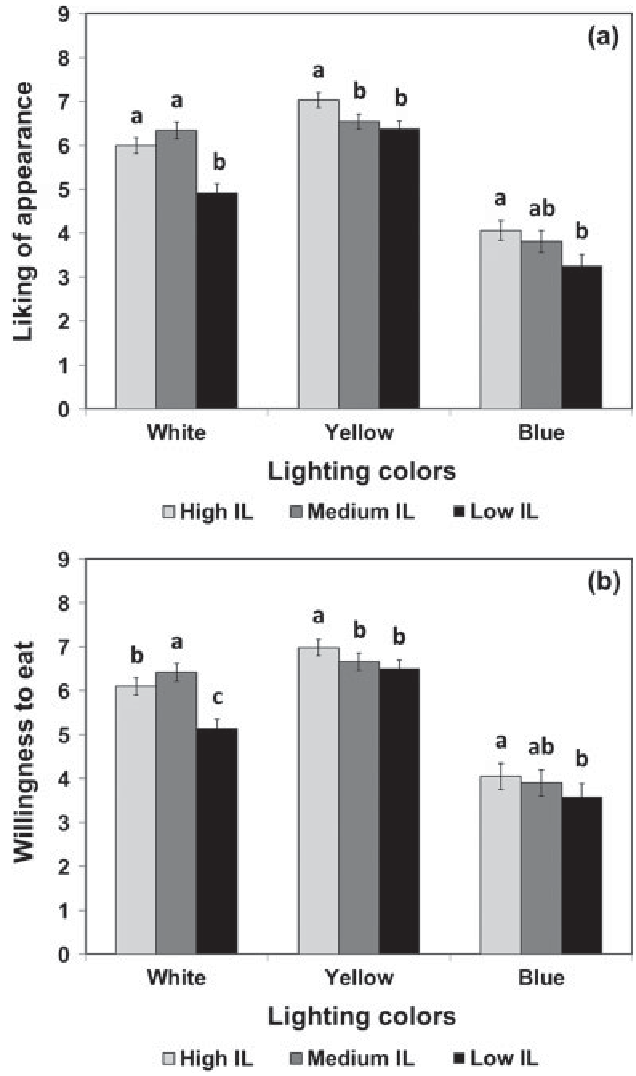

Figure 4. Mean differences in liking of appearance (a) and willingness to eat bell peppers (b) as a function of the level of lighting illuminance: low, medium, and high illuminance levels (IL). Means with different letters were significantly different from each other ($P < 0.05$). The error bars represent the standard errors of the means.

condition) medium and high levels of lighting illuminance produced higher liking of appearance and willingness to eat bell peppers. The outcomes are to some extent in agreement with the previous study[8] demonstrating that preferences of red and green bell peppers were increased under incandescent compared to under fluorescent and/or metal halide lighting sources. In that study, participants reported that the color of red bell peppers was bright red (70% of participants), dark red (65%), and deep red (65%) under incandescent, fluorescent and metal halide lighting sources, respectively.[8] As seen in Fig. 3, bell peppers are expected to be more easily recognized at medium and high levels of lighting illuminance compared to a low level of lighting illuminance; therefore, easier recognition might lead to an increase in liking of bell pepper appearance, thereby causing consumers to be more willing to eat the bell peppers. However, because the degree of recognition for the bell peppers was not assessed at each level of lighting illuminance, further research should be conducted to validate this idea.

GENERAL DISCUSSION

Our two experiments demonstrate that color and illuminance level of lighting can alter consumers' willingness to eat and acceptance of appearance in bell peppers. In both Experiments 1 and 2, yellow lighting appeared to enhance liking of appearance and willingness to eat bell peppers, whereas blue lighting appeared to decrease them. In addition, overall low level (dark) of lighting illuminance, in comparison to medium and high levels, reduced liking of appearance and willingness to eat bell peppers. It seems that yellow and bright lighting conditions make the surface colors of bell peppers more clear and natural. In contrast, both blue and dark lighting conditions distort or dim the natural colors of them, which may decrease liking of appearance, thereby lowering participants' willingness to eat.

As seen in Fig. 1, in blue and red lighting conditions participants might have more difficulty in obtaining detailed information about the bell peppers because the lighting colors alter the natural color, even shape, of bell peppers. From this perspective, the conflicting perception may cause uncertainty feelings,[29] which could consequently decrease hedonic tone and willingness to eat the bell peppers. In addition, when people experience difficulty judging certain food products (e.g. in the dark condition), they might hesitate or altogether avoid eating the food product.[30] Since we did not measure participants' individual uncertainty feeling and cognitive conflict for the bell peppers under blue and red lighting, this idea cannot be supported in this study. Further studies under controlled conditions should be conducted to determine whether ambient lighting-induced uncertainty or cognitive conflict can modulate consumers' willingness to eat the presented foods.

There was a significant interaction between the colors of bell pepper and lighting. For example, green lighting lessened liking of appearance and willingness to eat in red bell peppers, but not in green and yellow bell peppers. As seen in Fig. 1, the reflective color of lighting varies depending on the surface of bell peppers. This may be one plausible explanation for the interaction between colors of bell peppers and lighting when evaluating liking of appearance and willingness to eat. Similarly, Barbut[8,12] demonstrated interactions between surface color of foods (e.g. bell peppers and beef steaks) and source of lighting (i.e. incandescent, fluorescent and metal halide) in color preference of bell peppers. Specifically, incandescent lighting made colors of red and green bell peppers more natural, leading more participants to prefer these bell pepper colors under incandescent lighting, compared to fluorescent and metal halide lightings.[8] However, there was no significant difference between the sources of lighting for yellow bell pepper. Barbut[8] explained the interesting interactions based on differences in the relative luminance of bell peppers for three sources of lighting. For example, because fluorescent and metal halide lamps emitted minimal red light, they could not increase color preference of red foods (e.g. red bell pepper). However, color preference of yellow foods (e.g. yellow bell pepper) was not significantly different between fluorescent, metal halide and incandescent lamps because all three lamps emitted strong yellow light.

Color and brightness can modulate emotional status such as arousal.[31,32] Given that emotional status affects food choice and intake,[33] it can be thought that the lighting-induced emotion alters liking of appearance and willingness to eat the bell peppers. For example, bright and red light increase arousal and alertness by stimulating autonomic nervous system.[31,32] In this way, arousal status induced by bright and red light can modulate participants' liking of appearance and their willingness to eat. However, in this study, red lighting failed to show obvious changes in the willingness to eat bell peppers. Notably, emotion-induced food choice and consumption have not been consistently observed across previous studies. Numerous factors such as arousal (or intensity), hedonic valence, food relatedness of emotions, and restrained and emotional eating contribute to emotion-induced food choice and intake (for a review, see Macht[33]). Generally, high arousal appears to increase negative emotion and suppress eating.[33] In addition, it should be noted that participants received the photos of bell peppers taken under different lighting conditions. Furthermore, the photos of bell peppers were presented at individual booths lit with standard fluorescent lights because participants (especially the elderly participants) had difficulty looking at the scales on paper. That is, participants were not directly exposed to the lighting conditions, which could minimize the lighting-induced emotional changes in this study.

Under the present study's design, potential occurrence of first-order-carry-over effect[34] should be noted. For example, although the order of five lighting colors was randomized within each color of bell peppers, the order of bell pepper colors was not randomly distributed, which might induce the first-order-carry-over effect[34] in Experiment 1. Similarly, although the order of three levels of lighting illuminance was randomized within each color of lighting, the order of lighting color was not randomized in Experiment 2. As addressed above, participants were able to easily identify the bell peppers under white lighting, which might results in an expectation-induced bias in their ratings for the subsequent stimuli.[11,28] Therefore, a relatively less recognizable condition (i.e. the slide of bell peppers under blue lighting) was followed by the slides of bell peppers under yellow and white lightings. However, a possibility of the first-order-carry-over effect still remained in Experiment 2. Due to this methodological issue, the results of interaction between (1) colors of lighting and bell peppers (Experiment 1) and (2) colors and illuminance levels of lighting (Experiment 2) should be carefully interpreted.

To summarize, the current study supports and extends the notion that color and illuminance level of lighting can modulate food perception and motivation for consumption. Under controlled condition using LED lamps, our findings demonstrate that color and illuminance level of lighting influence not only liking of appearance, but also willingness to eat the bell peppers. Furthermore, the effects of color and illuminance level of lighting appear to be dependent on the surface color of bell peppers. Based on these results, consumers' intent to consume may be increased by employing specific lighting colors when displaying certain types of food products in retail environments. For example, red color food products (e.g. red meats and red apples) displayed under yellow lighting can be more attractive due to their increased colorfulness, thereby leading to an increase in in customers' willingness to purchase the products. However, in reality, general-purpose lamps such as incandescent and fluorescent lights have a limitation to produce specific lighting colors. At this point, replacing general-purpose lamps with multi-color LED bulbs might be beneficial by allowing us to apply specific color and illuminance levels to individual food products featured in retail and consumption environments. Indeed, colored LED lighting has been used in restaurants, bars, and clubs to manipulate ambient conditions for the purpose of inducing emotional changes (e.g. moody, relaxed, or stimulated status). Further, our findings suggest that colored LED lighting can be dynamically applied to increase consumers' appetite and acceptance for specific foods in restaurants and grocery stores. Finally, although the use of photographs appears to be a reliable alternative to presenting real foods in sensory testing,[24] real foods exposed under ambient lighting should be tested to generalize our findings.

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