Effect of the Colour Red on an Apple’s Deliciousness, Taste and Texture

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Abstract There remains a disagreement over the effects of colour, especially red and blue, on taste and appetite. Therefore, this study investigated the effects of different coloured apples on taste. Herein, Study 1 sampled four colour gradations from yellow (uncoloured) to red; Study 2 sampled four types of yellow (uncoloured), red, yellow-green and blue. All apples had the same taste as the colours were changed artificially. There were 30-32 participants, all of whom were 20-21-year-old students. All were generally healthy with normal vision, taste and appetite. The results of Study 1 demonstrated that the darker the shade of red, the less delicious food was perceived to be. Whereas, the results of Study 2 demonstrated that warm colours were perceived as more delicious than cold colours. Thus, these results indicate that food colour affects taste perception.

Keywords: coloured apple, adolescent, red


1. Introduction

Food colour influences taste and flavour perception in humans. Research has observed the effects of food colouring on human sensitivity to the four basic tastes [1-6]. However, few researchers have investigated this topic deeply and no unified view has been obtained [6].

Some have suggested that, in food, orange and red are the most preferred colours and blue and purple are the least, suggesting that warm colours stimulate the appetite more than cold colours [7,8]. However, other research found that red and blue colouring of visual food cues did not have the predicted effects on the desire for pictured foods [9]. These variable findings may mean that desirable colours depend on the type of food and/or the age of study participants. Moreover, the effect of colour on taste has not been examined in detail.

Studies have demonstrated how colours are perceived may vary by country. For example, a study that asked participants which of several different coloured drinks looks sweetest and found that responses varied across countries [7,10].

Appetite is affected not only by the colour of food itself but also by the colour of the plate that food is on. Food consumption during a meal has been found to differ depending on plate colour. A study found average total energy intake to be significantly higher when participants ate from red and black plates than white plates [11]. Genschow et al. suggested that serving food on red plates would reduce food consumption [12]. In a study that presented participants with a plate containing 16 pieces of bread marked, each marked with either a red or a green flag, fewer participants chose a piece of bread with a red flag compared with a green one [13]. This indicates that the colour red can act as an environmental stop cue even in a setting in which the colour is maximally salient. Further, research has supported this finding [12-16].

Research has been conducted on the colour red in contexts other than food. Hill and Barton demonstrated that in contests between individuals of similar ability, significantly more winners were wearing red than blue, suggesting that the colour of sportswear affects outcomes in sporting contexts [17]. Mehta and Zhu found that the activation of alternative motivations mediates the effect of colour on cognitive task performance [18]. Red and blue enhance performance on detail-oriented tasks and creative tasks, respectively [17,18]. However, few researchers have attempted to determine how colour affects food perception among young Japanese adults. We conducted two experiments in which apples were dyed different colours to clarify the effects of different colours on taste. We aimed to determine the effects of colour graduation and of cool (blue) and warm (red) colours on taste.

2. Materials and Methods

2.1. Participants

Study 1: Thirty-two recruited participants, 6 males and 26 females, were 20- and 21-year-old students who were...
generally healthy in their vision, taste and appetite. The study protocol was reviewed and approved by the School of Human Science and Environment Research Ethics Committee of Toyo University (TU-2019-006). The experimental procedure was carefully explained to all participants, and all participants provided their informed consent to participate in this study.

Study 2: Thirty recruited participants, 11 males and 19 females, were 20- and 21-year-old students who were generally healthy in their vision, taste, and appetite. The ethical procedure used was the same as that in study 1.

2.2. Study Design and Experimental Protocol

The method used for Study 1 was as follows. The variety of apple used was Kogyoku which is local scantily of type. We changed only the colourants and used the same cooking process to make apple compotes from differently coloured apples of the same variety. Standard deviation was used to perform the sensory evaluation. We evaluated nine items: tasty, texture, wateriness, bitter taste, sourness, sweetness, hardness, aroma, and appearance.

The method and questionnaire used for Study 2 were the same as those for Study 1, except that the type of apple used was San Fuji.

2.3. Photometric Measurements

Study 1: The colourimetric coordinates of the colours the apples used in Study 1 are presented in Table 1. In Study 1, we changed the colour from yellow (uncoloured) to red. To change the colouring, we used artificial colourants widely used in Japan which has no taste and no smell. The colour was confirmed by a colour difference metre (MINOLTA, CM-3500d). Brightness shows L*; Hue a* shows red to green; Hue b* shows blue to yellow. Sugar content was measured with a sugar content metre (ATAGO PAL-J). Hardness and adhesion were measured with a texture analyser (TA.XT.plus). Details of the photometric measurements and results are presented in Table 2.

Study 2: The colourimetric coordinates of the apples and the colours used are presented in Table 3. We changed the colour from yellow (uncoloured) to red, green, and blue. The colourants and measuring equipment were the same as those in Study 1. Details are presented in the results section in Table 4.

Table 1. Colourimetric coordinates of the yellow, orange, red (soft), and red (darker) colours used in this study

<table>
<thead>
<tr>
<th>Colour</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow (Uncoloured)</td>
<td>28.4±0.7</td>
<td>-2.2±0.6</td>
<td>7.4±0.1</td>
</tr>
<tr>
<td>Orange</td>
<td>41.2±7.4</td>
<td>7.3±2.3</td>
<td>10.9±5.0</td>
</tr>
<tr>
<td>Red (Soft)</td>
<td>39.6±8.2</td>
<td>10.1±5.4</td>
<td>23.6±10.7</td>
</tr>
<tr>
<td>Red (Darker)</td>
<td>40.5±13.0</td>
<td>10.8±4.5</td>
<td>10.3±6.1</td>
</tr>
</tbody>
</table>

L*: The L dimension of the space is roughly proportional to log-luminance and captures perceived changes along the black-white achromatic colour continuum. a, b: The a and b dimensions define a chromatic plane with axes corresponding to the red-green and blue-yellow opponent continua. N = 3, respectively. Numbers are Mean ± Standard Deviation.

Table 2. Sugar content and texture of four types of apples: yellow, orange, red (soft), and red (darker)

<table>
<thead>
<tr>
<th>Colour</th>
<th>Sugar content</th>
<th>Adhesiveness</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow (Uncoloured)</td>
<td>32.7±4.2</td>
<td>-0.04±0.00</td>
<td>1.1±0.5*</td>
</tr>
<tr>
<td>Orange</td>
<td>26.0±1.5</td>
<td>-0.06±0.05</td>
<td>1.6±0.4</td>
</tr>
<tr>
<td>Red (Soft)</td>
<td>28.9±4.1</td>
<td>-0.11±0.04</td>
<td>2.7±0.7*</td>
</tr>
<tr>
<td>Red (Darker)</td>
<td>31.6±0.4</td>
<td>-0.06±0.03</td>
<td>1.7±0.2</td>
</tr>
</tbody>
</table>

Sugar content is %. N = 3, respectively. Numbers are Mean ± Standard Deviation. *: Hardness by group is significant based on a one-way analysis of variance. #: There are significant a* by each groups by one-way ANOVA. **P < 0.01

Table 3. Colourimetric coordinates of the yellow, red, green, and blue colours used in the study

<table>
<thead>
<tr>
<th>Colour</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow (Uncoloured)</td>
<td>53.3±2.3</td>
<td>-1.1±0.7</td>
<td>18.5±3.7</td>
</tr>
<tr>
<td>Red</td>
<td>43.6±4.2</td>
<td>9.6±1.3</td>
<td>13.6±1.2</td>
</tr>
<tr>
<td>Green</td>
<td>46.1±8.4</td>
<td>-9.6±2.2</td>
<td>16.2±4.7</td>
</tr>
<tr>
<td>Blue</td>
<td>49.1±3.6</td>
<td>-9.2±1.7</td>
<td>12.4±2.3</td>
</tr>
</tbody>
</table>

L*: The L dimension of the space is roughly proportional to log-luminance and captures perceived changes along the black-white achromatic colour continuum.

Table 4. Sugar content and texture of four types of apples: yellow, red, green, and blue

<table>
<thead>
<tr>
<th>Colour</th>
<th>Sugar content</th>
<th>Adhesiveness</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow (Uncoloured)</td>
<td>28.6±3.4</td>
<td>-0.07±0.04</td>
<td>5.2±1.0*</td>
</tr>
<tr>
<td>Red</td>
<td>26.1±0.9</td>
<td>-0.16±0.08</td>
<td>8.9±1.1b</td>
</tr>
<tr>
<td>Green</td>
<td>27.1±2.7</td>
<td>-0.12±0.05</td>
<td>3.8±1.5b</td>
</tr>
<tr>
<td>Blue</td>
<td>23.4±1.2</td>
<td>-0.19±0.04</td>
<td>8.6±0.6a</td>
</tr>
</tbody>
</table>

Sugar content is %. N = 3, respectively. Numbers are Mean ± Standard Deviation. *: Hardness by group is significant based on one-way ANOVA. **P < 0.01

2.4. Statistical Analysis

Data analysis was conducted with the Statistical Package for the Social Sciences version 25 (SPSS Inc., Chicago, IL, USA). Data are presented as the mean ± standard error of mean unless otherwise stated. To compare the quality of the four coloured apples intently sugar content, adhesiveness and hardness, we used one-way analysis of variance (ANOVA) for data analysis. The primary outcome of this trial was the effect of differently coloured apples on three items: taste preference, delicious, and texture. For the primary out-come, data were analysed by using the Kruskal-Wallis test. For the secondary outcome, data were analysed by using the Mann-Whitney U test. P < 0.05 was considered statistically significant. Statistical analysis was the same as that in study 1 and 2.
3. Results

3.1. Study 1

The yellow-coloured (uncoloured) apple was considered the tastiest, followed by the orange apple (Figure 1). The darker the red was the less delicious the apple was reported to be. In addition, significant differences were observed in hardness, texture, and astringency. The darker the colour, the less crispy and more astringent the apple was reported to be (Figure 1). In addition, no significant differences were observed in sweetness and sour, aroma, and wateriness.

For the colours yellow and red, machine measurements and sensory evaluations provided similar results (Table 2, Figure 1). Regarding the perceived texture of the red-coloured apple, it affected taste and appearance, and its overall effect remained unknown.

3.2. Study 2

The second survey was conducted at different facilities and at a different time from the first survey. However, the factors extracted from both surveys coincided, except that the order of the first and second factors and of the third and fourth factors were switched.

Figure 1. Results of the sensory evaluation of eating red-coloured apples (Evaluated example by a 5-point Likert scale from 1 (extremely weak) to 5 (extremely strong)). Kruskal-Wallis test, *P < 0.05, **P < 0.01, ***P < 0.001. Mann-Whitney U test, A vs B #, A vs C !, B vs C $, C vs D &, A vs D +, # P < 0.05, ## P < 0.01, ### P < 0.001. The same number indicates the same level, even with different symbols.

Figure 2. Results of the sensory evaluation of eating apples coloured yellow, red, green, and blue (Evaluated example by a 5-point Likert scale 1 (extremely weak) to 5 (extremely strong)). Kruskal-Wallis test, *P < 0.05, **P < 0.01, ***P < 0.001. Mann-Whitney U test, A vs B #, A vs C !, B vs C $, C vs D &, A vs D +, # P < 0.05, ## P < 0.01, ### P < 0.001. The same number indicates the same level, even with different symbols.
No significant differences were observed for sweetness items and each colour. Significant differences were observed for the eight items other than the sweetness items and each colour. The colour most associated with a tasty apple was yellow (uncoloured), followed by red (Figure 2).

For the green apple, participants reported that the texture was tough and the hardness was soft. Notably, a significant difference in hardness was reported in yellow versus blue and red versus green (P < 0.05, Table 4). For texture, the same results as those measured by a machine were obtained, but significant differences were observed between colours. For example, the mechanical measurement demonstrated a significant difference between yellow and blue, but a sensory evaluation demonstrated no significant difference.

4. Discussion

We used artificial colouring agents to change the colour of different samples of the same apple compote to assess differences in taste perception and enjoyment based on colour. We performed two using different colour combinations. In Study 1, we found that the taste of darker reds was perceived as less enjoyable than lighter reds. In Study 2, we found that the warm (red) coloured apple compote was perceived to taste better than the cool (blue) coloured compote.

Zellner and Durlach found that respondents expected colours from red to yellow on the spectrum to be more refreshing than those from green to purple [19]. Okuda et al. found that red, orange and yellow increase appetite and black, brown, purple and blue decrease appetite [20]. In contrast, our results demonstrated that the darker the red colour, the less delicious it was judged to be (Figure 1). When the participants compared the red, green and blue-coloured compotes, red was perceived to taste better than blue or green (Figure 2). Given the result of Study 1, colour density is important and red may not simply be an appetite booster. On the other hand, the results of Study 2 comparing red and blue are similar to Okuda et al. To the best of our knowledge, no studies of taste that varied the depth of food colours have been carried out. The colour of candy wrappers and beverage containers has been found to influence flavour expectations but not the perception of actual taste. These results suggest that food colour affects the perception of flavour more than package colour [21,22]. In the present study, combinations of colour may have affected taste perceptions.

Blue foods are rarer in nature than foods of other colours [23]. According to previous research, blue food is disliked because in humans’ evolutionary past, blue foods were likely to be mouldy and would be avoided to prevent food poisoning [24,25]. Our study demonstrated that perceptions of taste, hardness, aroma and other characteristics of food significantly differed for red and blue-coloured food (Figure 2). We concluded that colour affects taste perceptions (Table 4). However, a previous study demonstrated no significant differences in perceptions of taste and aroma for soup of different colours [25].

In our study, the colour green produced characteristic results (Table 4 and Figure 2). Participants perceived the green food to have a softer texture than the other colours. In addition, it indicates that human perception may be more sensitive than mechanical measurements. Possible support for this result is from a study that found jelly tastes associated with the colour green are melon, green apple and muscat. In another survey on Japanese individuals of a similar age to the participants in our study, ice cream and drink flavours associated with the colour green were matcha, melon and muscat [26]. Thus, green may have been perceived as softer than that of other colours in our study because green reminds people of certain fruit. Kondo and Kobayashi have described the effect of visual images on taste as a cross-modality effect [27]. Narumi found that individuals holding an image of something sweet in their minds perceive food as tasting sweeter than those holding an image of something sour in their minds [28]. Preconceptions may affect taste perception more than colour does. When Maric and Jacquot asked participants to relate olfactory stimuli to colours, those people associated with the colour green were cucumber and peppermint [29]. Taken together, the above findings suggest that the foods people associate with particular colours differ for smell and taste. This may be attributable to the cross-modal effect mentioned above [30]. Schuldt found that green labels on food increase the perceived healthfulness of the product, especially among consumers who place high importance on healthy eating [31]. Health consciousness may be a factor relevant to our perceptions about the colour green. Further research on this is necessary.

This study had a few limitations. We did not test each participant’s basic sense of taste or assess for colour blindness. We also did not consider their physiological brain functions. Participants were not asked to supply this information. We assumed that these factors did not affect the results because the participants were able to live normal, functional lives. Additionally, we did not assess the effects of artificial colourings on taste. However, researchers aware of our study confirmed that they could perceive no difference in the taste of food after it had been artificially coloured. This also suggests that red pigment is not affected by the colourant (Table 2). The results of this study can be applied to research into obesity, gustatory impairment and the development of taste preferences in children, potentially leading to improved health and quality of life among these demographics. Brunk and Moller investigated whether plate colour affected the acceptance of new foods in children of different ages [32]. Our results might also differ in participants of different ages and cultural backgrounds [33]. Generalising our results to other age groups and ethnicities and other foods requires further research.

5. Conclusion

The results demonstrated that the darker the shade of red, the less delicious food was perceived to be. In addition, we observed that young Japanese adults perceive the taste, texture and aroma of red-coloured food...
as more appealing than blue-coloured food. These results suggest that food colour affects taste perception. Taste may be perceived differently depending on the colour of food or the combination of the colours.

Acknowledgements

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References


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