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RESEARCH ARTICLE

The influence of color on taste perception

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ABSTRACT

Background: Taste perception is a highly subjective process that involves the other special senses as well. The visual and olfactory signals play an important role in perception of taste. We use visual cues from color to identify and judge the quality and taste of what we eat. Color has a major impact on taste perception which seems to influence our taste buds more than olfactory sense. **Aim and Objective:** The objective of present study was to assess the influence of color of sucrose solution on its taste perception. **Materials and Methods:** About 53 female subjects in the age group of 17–20 years were asked to taste a fixed quantity of the sucrose solution of six different colors of same sucrose concentration. The subjects were asked to rate them according to sweetness scale of 1–10. The mean and standard deviation of the scores was obtained. **Results:** The purple colored solution was rated as highest sweetness (6.09 ± 2.09) followed by blue (5.9 ± 1.9), green (5.62 ± 1.97), red (5.11 ± 1.63), and yellow (4.20 ± 1.75). **Conclusion:** The clear sucrose solution was rated the same as the purple solution. The colors like purple and blue were perceived sweeter compared to red and yellow indicating that color of the solution does influence the perception of its taste**.**

KEY WORDS: Taste; Color; Perception

INTRODUCTION

Taste perception varies from person to person and is a highly subjective process. Prior research has established a strong link between odor and taste, by smelling it directly (orthonasally) or in conjunction with tasting (retronasally). There is also direct contribution to taste perception by gustatory, olfactory, and oral–somatosensory signals.[1] Taste perception is incomplete without proper visual cues. The familiarity with a certain foodstuff may result in identifying it with a particular taste as brain identifies each foodstuff in a particular form. The hypothalamus associates the taste and flavor of food to its appearance and thus integrates the memory of taste perception.[2] Color plays an important role in food products that we consume every day. The appearance of food has an important role in selection of food by humans along with its taste and smell. Individual expectations regarding the appearance of food are determined by both genetics and their upbringing.[3,4] Color is one of the most important sensory cue regarding people's expectation of taste and flavor of food. We can see color-taste associations in nature like ripening of fruit, where red color is associated with sweetness and green with sourness of fruit. In different parts of the world, various types of food are available in varied colors, adding further to color-taste associations. Food color can also provide important information regarding safety of consuming a particular food. The color of food may change when the food is spoilt and is no longer palatable. Research has shown major influence on the expectations and experiences of consumers when the color of food and beverages or its intensity was changed. It

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was noted to have a negative influence when the expected color did not match with the taste of the food.[5]

The association of color with varied foodstuff begins from birth in humans and continues throughout life thus leading to identification of certain tastes and flavors with particular colors. The cultural difference in different parts of world may also influence such association of taste with color.[6] Research has suggested that colour may also contribute to optimal selection of foods. Color of food may aide to its aesthetics and also there is a cultural belief that identifies that the consumption of colorful food as the essence of good eating.[7] There are different expectations regarding food colors in various cultures and age groups. There could be genetic modulation of psychological impact of food color on flavor perception.[5] Research has shown that food with added colors had a stronger and more powerful aroma compared to those without added color.[8] It has been observed previously that perceived taste is greatest with middle range intensities of color.[9] The flavor/taste perception is also affected by external factors such as color of the serving bowl or illumination of the surrounding place which are not physically a part of the food.[10,11] This influence has been largely exploited by hotel business, to make their food products more appealing to their customers. Branding by companies also plays an important psychological role in perception.[12] Color of food product is one of the important factor that determines the acceptance of the consumers as they associate specific colors with particular tastes and flavors, and changing their color may negatively influence its taste/flavor perception. Although taste and flavor are commonly used interchangeably, taste refers to the perception of basic tastes identified by the taste receptors in the oral cavity whereas "flavor" involves olfaction in addition to taste. The color of cups, cutlery, plates, packages, and the color of the surrounding environment may have an influence on the multisensory flavor perception.[2,13] This explains the reason behind better consumer ratings seen with regards to good ambience of the restaurant and thus demonstrates the importance of associated factors with regards to taste of food. The understanding of the various sensory and other expectations of different individuals as elicited by food color may lead to better understanding of modulation of multisensory perception of flavor by color cues and also explains about varied liking and aversion shown for a particular food product.[5]

Sweetness is one of the basic taste modality and desire for sweet taste is seen across all ages, races, and cultures. There is more attraction toward sweet taste by infants and young children as they are exposed to milk from birth which is rich in lactose and has sweet taste. Sweetness plays an important role as a source of energy and nutrition throughout evolution which determines the feeding behavior. Visual information such as the color of food or drink influences our expectations regarding its sensory properties such as flavor, aroma/odor, and its perceived taste. It is also seen that color as a role in influencing our food and drink-related behavior as it has been rightly suggested that "we eat first with our eyes".[14] The previous researchers have not assessed in great deal the effect of color on the identification of basic tastes like sugar or salt; therefore, the information on influence of color of food on basic taste like sweetness is limited. Thus, the present study was undertaken with the objective of assessing the effect of color of sucrose solution on perception of its sweetness.

MATERIALS AND METHODS

The present study was conducted in the Department of Physiology, Kempegowda Institute of medical Sciences, Bangalore. Fifty-three female medical students in the age group of 17–20 years with normal color vision and gustatory ability who volunteered for the study were recruited as subjects. The participants were tested by Ishihara's chart in day light to rule out color blindness. Participants with cold or other respiratory tract infection 1 week before the study or those with any medical ailments like diabetes mellitus were excluded from the study. Written informed consent was taken by the subjects before the study. The study was approved by the institutional ethical committee and ethical clearance certificate was obtained. Information regarding the favorite color and taste of the participants, their present and past exposure to a varied diet, importance of food color to them, and their last menstrual period was collected by the participants.

Study Design

Subjects were asked to report 2 h after their last meal and were seated comfortably in a quiet room with adequate lighting. Six transparent plastic cups containing sucrose solutions of different colors were given to the subjects. The sucrose solution was prepared by adding 100 g of sucrose in a liter of water. The solution was divided into six portions and one drop of different colors of food coloring (Wilton Industries, No-Taste Food Coloring) was added to each portion and were colored red, green, purple, yellow, blue, and one was left colorless. All of the food colorings used in the present study were tasteless. The colorless sample consisted of only sucrose solution. The sucrose solutions were all of the same concentration (10 g/dL). The participants were asked to taste a fixed volume (0.5 mL) of the sucrose solution from the cups with help of a dropper exclusive for each cup. They were instructed to rinse their mouth with water after tasting each solution. Subjects were asked to rate each solution according to perceived sweetness, on a scale of 1–10 where maximum sweetness is indicated by 10 and least by 1.

Statistical Analysis

The data were analyzed using SPSS software 15.0. The data were tested for normal distribution and found the variables

were non-normal; hence, non-parametric testes were used. The mean and standard deviation of the scores was obtained. The Mann–Whitney test was done to assess the variables. $P \leq 0.05$ was considered significant.

RESULTS

A total of 53 female students were included in the study. The age groups included were 17–20 years and the mean age was 18.36 ± 0.62 years. The overall mean sweetness scores rated for different sugar solutions were 6.09 ± 2.09 for purple, 5.9 ± 1.9 for blue, 5.62 ± 1.97 for green, 5.11 ± 1.63 for red, and 4.20 ± 1.75 for yellow. The colorless sugar solution was rated the same as the purple solution. The perception of sweetness was highest with purple colored solution and least with yellow colored solution, and colorless solution was also rated higher than the colored solutions [Table 1].

Importance to Food Color and Sweetness Scores

Based on the importance placed by subjects on the color of the food, about 93% of the subjects said that food color mattered to them while choosing food (Very Important/ Important/Somewhat Important), 7% said that food colour was not important. The mean sweetness scores in subjects placing importance on color was maximum (6.06 ± 2.15) for purple, with the colorless solution was rated as 6.18 ± 2.45. The subjects who did not show importance to color of the food rated purple solution as 6.5 ± 1.29, blue as 5.25 ± 1.26, green as 4 ± 0.82, red as 2.75 ± 1.26, and yellow solution as 2.5 ± 1.73. The colorless solution was rated as 5 ± 2.58 [Table 2].

Favorite Taste and Sweetness Scores

Based on their favorite taste, about 51% of the participants had preference for sweet taste, 36% for spicy, 7% for sour, and the remaining 6% for salty taste. The mean sweetness scores rated for different sugar solutions by subjects with preference for sweet taste were maximum (6 ± 2.02) for blue, followed by purple, red, yellow, and with the colorless sugar solution being rated as 5.89 ± 2.45. Subjects with preference for other tastes rated 6.38 ± 1.68 for purple colored solution, 5.81 ± 1.81 for blue, 5.77 ± 2.03 for green, 5.08 ± 1.57 for red, and 4.15 ± 1.59 for yellow solution. The colorless solution was rated as 6.31 ± 2.48 [Table 3].

Table 1: Grading of sweetness of different color solutions

Color of solution	Mean	±Standard deviation
Colorless	6.09	2.45
Yellow	4.20	1.75
Red	5.11	1.63
Green	5.62	1.97
Blue	5.90	1.90
Purple	6.09	2.09

Favorite Color and Sweetness Scores

Based on their favorite color, about 19% of the participants reported blue as their favorite color, 13% as red, 11% as purple, 6% as green, and the remaining as other colors. None of the participants reported yellow as their favourite colour. The mean sweetness scores rated for different sugar solutions by subjects with blue as their favorite color rated the highest (6.5 ± 1.78) for blue, followed by purple, green, red, and yellow, but the colorless solution was rated higher with 6.8 ± 2.25. Subjects with red as their favorite color rated the solutions as 6 ± 1.41 for red, followed by green, blue, purple, yellow, and colorless solutions. The sweetness scores by subjects with purple as favorite color was 6.67 ± 2.66 for purple, followed by blue, green, red, and yellow, but the colorless solution was rated as 5.33 ± 3.27. The subjects with green as favorite color rated the sugar solutions as 6.67 ± 2.52 for purple, followed by blue, green, yellow, and red. The colorless solution was rated as 5.33 ± 2.52. The sweetness ratings by rest of the subjects with other favorite colors were 6.15 ± 2.07 for purple, 6 ± 1.8 for blue, 5.74 ± 2.03 for green, 5.11 ± 1.76 for red, and 4.33 ± 2.04 for yellow solutions. The colorless solution was rated as 6.48 ± 2.28 by them [Table 4].

Varied Diet and Sweetness Scores

About 97% of the participants were currently exposed to varied diet and 87% were previously exposed to varied diet. Only 10% of the subjects are not exposed to varied diet currently and 13% were not exposed previously. The sweetness scores rated by the subjects exposed to varied diet previously were 6.17 ± 2.05 for purple, followed by blue, green, red, and yellow solutions. They rated colorless solution as 6.28 ± 2.37. Among subjects who were not exposed to varied diet previously the sweetness scores were 5.57 ± 2.51 for purple, 5.57 ± 1.72 for green, and lower for

Table 2: Grading of sweetness based on subject's response on personal importance of color

Importance of food color	Colorless (mean±SD)	Yellow (mean±SD)	Red (mean±SD)	Green (mean±SD)	Blue (mean±SD)	Purple (mean±SD)
Very important (10)	7.4±1.35	4.2±1.87	4.9±1.52	5.3±2.00	6.2±0.79	7.3±1.64
Important (22)	6.19±2.64	4.43±1.69	5.76±1.73	6.29±1.93	6.10±2.05	5.76±1.79
Somewhat important (18)	5.5±2.53	4.33±1.71	5±1.14	5.39±2.00	5.67±2.30	5.72±2.61
Not important (4)	5±2.58	2.5±1.73	2.75±1.26	4±0.82	5.25±1.26	6.5±1.29

Table 3: Grading of sweetness based on their favorite taste

Favorite taste	Colorless (mean±SD)	Yellow (mean±SD)	Red (mean±SD)	Green (mean±SD)	Blue (mean±SD)	Purple (mean±SD)
Sweet (27)	5.89±2.45	4.26±1.93	5.15±1.73	5.48±1.95	6±2.02	5.81±2.43
Spicy (19)	5.42±2.24	4.21±1.47	4.95±1.61	5.11±1.73	5.42±1.68	6.16±1.68
Sour (4)	8.5±0.58	4±1.83	5.25±0.96	6.5±1.29	6.25±2.06	8±1.41
Salty (3)	9±1.73	4±2.65	5.67±2.31	9±1	7.67±1.53	5.67±0.58

Table 4: Grading of sweetness based on their favorite color

Favorite color	Colorless solution (mean±SD)	Yellow solution (mean±SD)	Red solution (mean±SD)	Green solution (mean±SD)	Blue solution (mean±SD)	Purple solution (mean±SD)
Black (12)	6.25±2.49	4.08±1.78	4.83±1.75	5.83±2.21	5.5±1.57	6.08±1.24
Blue (10)	6.8±2.25	4±1.56	5.2±1.4	5.8±2.35	6.5±1.78	6.3±1.06
Green (3)	5.33±2.52	3.67±1.15	3.33±0.58	4.67±1.15	5±2	6.67±2.52
Purple (6)	5.33±3.27	4.33±1.75	5±1.79	5.83±2.04	5.83±1.94	6.67±2.66
Red (6)	4.33±2.58	4.33±1.37	6±1.41	5.33±1.75	5±2.76	4.83±2.99
Pink (5)	7.6±0.89	4.6±3.21	5±2	4.8±1.1	6.6±0.55	7.8±1.3
Violet (3)	8±1	4.67±3.06	5±2	6.33±2.52	8.67±0.58	5.67±4.51
White (3)	4.67±3.06	4.67±2.08	6±1.73	6.33±3.21	4.67±1.53	5.33±0.58

blue, red, and yellow and 4.86 ± 2.79 for colorless solution. The subjects exposed to varied diet currently rated the sugar solutions as 6.02 ± 2.14 for purple, followed by blue, green, red, and yellow solutions, with the colorless solution as 5.94 ± 2.52. Among the subjects currently not exposed to varied diet the ratings were 6.8 ± 1.64 for purple, 6.4 ± 1.52 for blue, 5.4 ± 1.52 for green, 4.4 ± 1.14 for red, 3.4 ± 1.82 for yellow, and highest (7.6 ± 0.55) for colorless solutions [Table 5].

DISCUSSION

The perception of sweetness was highest with purple colored solution and least with yellow colored solution. The mean sweetness scores were maximum for purple colored solution in both the groups of participants based on importance of food color to them. The subjects with preference for sweet taste rated maximum sweetness for blue color solution whereas subjects with preference for other tastes rated maximum sweetness for purple colored solution. Subjects with red as their favorite color rated the solutions as higher sweetness for red colored solution, followed by green, blue, purple, yellow, and colorless solutions. The sweetness scores of subjects with purple as favorite color were highest for purple followed by blue, green, red, and yellow. The subjects with green as favorite color rated maximum for purple color solution, followed by blue, green, yellow, and red. The sweetness rating by rest of the subjects with other favorite colors was higher for purple solution. There was no difference in sweetness ratings of participants based on their exposure to varied diet as both the groups rated higher sweetness for purple colored solution. There is a general trend in the ratings, with the purple and blue colored solutions generally being rated higher in sweetness than the others, and surprisingly a higher rating for the colorless solution.

The literature shows a significant change in judgment of flavor and/or taste intensity by people in response to alteration of intensity of the color added to the food.[9] Taste is the most important driving force with regards to food choice and basic taste like sweetness is innately liked by humans from birth. This was also observed in the present study as more than half of study population stated sweet as their favorite taste. The multisensory experience of a food product is associated with many factors. Both intrinsic and extrinsic factors of food product like internal value of food itself and external factors such as packaging or surrounding environment may play a role in the perception of food and this in turn determines our acceptance of food to be selected for consumption. The previous studies have observed correlation between flavor and odor.[15] Demattè *et al*. observed the association between odor and color and this explains the form of associative learning where there is systematic combination of olfactory and color properties of an object.[8] The color-flavor association in identification of drink was observed by Oram *et al*. and it was noticed that influenced by flavor was greater in older children which suggests that the perception sense maturates with age.[16] The previous studies have observed that when intensity of food coloring was increased across a range of different drinks, it had a significant effect on ratings of its taste or flavor intensity by the consumers.[9] The present findings corroborate with the previous study where consumers expectation regarding intensity of taste/flavor of food and beverages increased when they were colored intensely. The researchers have observed an increase in the perception of sweetness on addition of food coloring.[5] The previous

Table 5: Grading of sweetness based on their exposure to varied diet

Solutions	Varied previous diet		Varied current diet	
	Present (46) (mean±SD)	Absent (7) (mean±SD)	Present (48) (mean±SD)	Absent (5) (mean±SD)
Colorless	6.28±2.37	4.86±2.79	5.94±2.52	7.6±0.55
Yellow	4.24±1.84	4±1.15	4.29±1.75	3.4±1.82
Red	5.22±1.69	4.43±1.13	5.19±1.67	4.4±1.14
Green	5.63±2.03	5.57±1.72	5.65±2.03	5.4±1.52
Blue	6.07±1.87	4.86±1.95	5.85±1.95	6.4±1.52
Purple	6.17±2.05	5.57±2.51	6.02±2.14	6.8±1.64

studies have observed that the external factors like color and weight of the container affects perception of flavor of the beverage. These findings throw light on the influence of both external and internal factors on perception of flavor of the food, and thus highlights the importance of both internal product and its external packaging in the design of food products,[17] while some studies have failed to exhibit any association between external factors and flavor perception.[18] The literature suggests that in humans, color of the food has a powerful crossmodal influence on perception of its flavor. Humans generally associate a particular color with a specific flavor and these food color–flavor associations can remain despite extensive experience with the particular food item concerned and there is also a tendency to maintain beliefs that are inappropriate when food is colored differently.[19] The effect of color on perception of four basic tastes such as salty, sour, sweet, and bitter was investigated by Maga by coloring the solutions red, green, and yellow. Perception of sweetness was observed to be more in green solution compared to red and yellow which is consistence to the findings in the present study.[20] There was no influence of color on saltiness perception suggesting that color may not influence salt perception.[20] Some studies have shown only a weak influence of color of beverage on perception of its taste with certain exceptions.[21] However, a positive association between red color and sweetness was demonstrated by Koch and Koch hat is in contrast to the findings of present study where red color sucrose solution was rated less sweeter.[22] Johnson and Clydesdale observed an alteration in perception of sweetness, when odorless red colored sucrose solutions were tested with varied intensity of color, and it was noted that darker-colored solutions were rated sweeter than the lighter-colored solutions by the participants and sweetness rating was also high in the colorless solution.[9] These findings are similar to the obtained result in the present study. The present findings show a very rating for the colorless solution in most instances and substantiate the findings of other studies in which colored drinks are compared to clear drinks. This may be explained by the fact that food in its natural state is perceived to have the strongest taste.[20,23] In younger age group sweetness seem to be more strongly associated to specific flavor than to specific colors. These differences between adults and younger age group in sweetness perception could arise from experiences associated with the product since childhood.[15,23] The higher sweetness scores observed in the present study for purple and blue color can be looked from two perspectives. Most mammals other than humans have red-green color blindness that is they are able to see violet, blue, green, and yellow light but not red and orange light thus leading to an evolutionary bias toward purple and blue, which may be the reason for greater sweetness perception of these colors.[24] Contrary to evolutionary perspective, as a consequence of recent advancements in marketing field where unorthodox colors like blue and purple are paired with familiar flavors, this may cause a cognitive effect on intensity perception by conditioning the children.[25,26] There was a general trend towards purple and colorless solutions in those with varied diets, whereas those with non-varied diets showed the largest discrepancy from the general trend. The development of food preferences in children is influenced by many factors, as the child is exposed even before birth to many flavors from the diet of the mother and there is experience with sweetness in human milk immediately after birth. Allen *et al*. suggested that there may be intrinsic genetic basis for taste perception,[3] but other authors contradict this and suggest that taste can be taught by use of artificial sweeteners in children, thus explains the importance of exposure to varied diet that, in turn, may influence the perception of sweetness.[4] Zampini *et al*. noted that there was impairment of flavor identification, when the flavors were not paired with conventional colors that are associated with them.[27] Thus, there is specific expectations regarding the likely flavor of the food and also its taste based on visual appearance and is determined by previous experiences of food from birth.[28] Research has observed that there is varied response to specific colors by different cultural backgrounds across the world,[28,29] which is eliminated in this particular scenario as all participants were Indian. Liem and Mennella observed that when children are repeatedly exposed to a particular taste, there is development of preference to that taste by them. This may explain the innate preference for sweet tastes as they have consumed milk containing sugars from birth.[30] Expertise acquired when a particular type of foodstuff is tasted frequently,[31] and experience acquired by as age advances may also cause variation of intensity perception,[16] which was eliminated in the present study by limiting the age group and inexperience of the study subjects. In the present study, the males were not included as there could be gender disparity in perception of sweetness based on

color. Sensory integration in females is comparatively more precise since they have larger corpus callosum which further justifies their inclusion in the present study. Researchers have noted that women in particular are more sensitive than men in identifying specific odorants.[32] This can be explained by the fact that integration between different sensory modalities is more advanced in women and thus they can precisely observe the influence of color in perception of sweetness.[33] Females have more liking toward color including the food products and thus explains the association between favorite color and sweetness perception observed in our study wherein the sucrose solution was perceived sweeter when it matched with their favorite color. Taste perception is a highly personalized experience, there seems to be a perception of greater sweetness intensity with colors like purple and blue, compared to red and yellow. The perception of sweetness is least with yellow color unlike previous studies where red and yellow was perceived sweeter.[22] The findings of the present study suggests that color does have an influence on the perception of taste**,** with lower wavelength colored solutions being rated higher, except the colorless solution. Most foods that are consumed contain high quantity of endogenous natural sugars or sugars have been added during processing. There is continuous desire for sweetened products by the consumers; therefore it is necessary to reduce added sugars in food products because of health risks such as cardiovascular disease, diabetes, and obesity associated with overuse of added sugars. The desired perception of sweetness in food products can also be achieved by only changing the intensity of its color as observed in the present study.

Strength and Limitations

The participants involved in the present study were females thus reducing the gender bias involved in perception of color. Various factors such as the subject's preference for food color, their exposure to varied diet, their favorite color, and taste that may influence the perception of sweetness based on color of sucrose solution have been considered. The limitation of the present study is that influence of color on perception of other taste sensation such as sour, salt, and bitter was not considered. Males were not included in the study and thus the gender difference in perception of sweetness based on color was not possible. Therefore, there is a scope for further research in a larger population to explore difference in the influence of color of food on taste perception in both the gender and also on different taste modalities other than sweetness.

CONCLUSION

The study shows that the color of food unambiguously does affect the perception of taste intensity. This has further implications in studies of the multisensory integration in the field of neuroscience. Food and beverage industry may also be benefitted by the current findings, where sugar content of foodstuff can be reduced without affecting perceived taste by using specific colors. The results can also be of use in pharmaceutical industry to increase palatability of drugs, especially in pediatric medicine as children have more liking for sweetness and can be applied in the enhancement of the diabetic diet.

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