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Can Colour Create Value in the Food Market? A Systematic Literature Review on the Relationship between Colour and Consumer Perceptions

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Abstract

It was traditionally believed that consumer perception of a food/drink product was, and could only be, influenced by that product's intrinsic properties. Extrinsic properties such as colour were not paid much attention. Since the early 1970s a range of different studies have been done on how a certain colour, whether being incorporated in the food/drink itself, or as part of the packaging design, could potentially affect consumers' taste/flavour perception and acceptability of that foodstuff. This paper uses a systematic literature review method to review findings regarding the colour-perception associations, and to categorise them. The aim is to provide meaningful recommendations for the food processing industry, as well as for possible future experiments. Overall, based on the literature reviewed, it is shown that colour does exert an influence on consumers' taste/flavour perception of a food, and the intensity of the colour also makes a difference. Colours that are used as a food background (e.g. packaging, crockery) are also shown to influence consumers' perception, sometimes even their behaviour. Taking cultural and age differences into consideration, the food industry can use colour to a greater extent as a technique to add value to their food/drink products.

Introduction

The food industry has spent decades trying to study consumer preferences and their willingness to purchase certain food/beverage products, to assist in improving consumer loyalty and sustainability of the business. It was widely believed (especially in the field of economics) that consumers' experienced pleasantness was, and could only be, influenced by a product's intrinsic properties and the consumers' state when the transaction took place (Kahneman, Wakker and Sarin, 1997).

However, over time, the food industry has realized that consumers' perceptions towards a given food/drink item are affected by a combination of intrinsic and extrinsic factors in a complex manner. Information received by one's gustatory, oral-somatosensory, olfactory (Spence, Levitan, Shankar and Zampini, 2010), and even visual systems is all being processed simultaneously when a consumer is making a decision or evaluating a product.

As a result, many food and beverage manufacturing firms have adopted marketing strategies that involve changing a good's extrinsic properties, such as pricing, in attempts to enhance their consumers' experienced pleasantness (Plassmann, O'Doherty, Shiv and Rangel, 2008). Once this is established, it functions as a learning signal for the brain to guide future purchases (Plassmann et al., 2008). This is particularly valuable for companies that have their focus set on securing consumer loyalty.

Extrinsic characteristics that influence consumer behavior or perception can range from something straightforward like prices and brand name to something more complicated like the colour of the packaging. A number of studies carried out in the past focused on the relationship between colours and taste/flavour perceptions. This colour component can be integrated into a food/beverage item and can both positively and negatively impact consumers' perceptions towards the product in different ways. For instance, food colourants can be added directly into a food/drink product to alter its colour and colour intensity (e.g. DuBose, Cardello and Maller, 1980; Bayarri, Calvo, Costell and Duran, 2001; Zampini, Sanabria, Phillips and Spence, 2007), or certain colours can be chosen as part of the food packaging design and act as a visual cue (e.g. Villegas, Carbonell and Costell, 2008; Mead and Richerson, 2018).

Nonetheless, while considerable research has been done on the influence of colour on consumers' perceptions and behaviours towards food/beverage products, limited information has been provided about how these findings could be integrated and bring value to the food industry.

The broad aim of this project is to determine if colour can be used as a food element to add value to food and beverage products, and to their respective businesses. The specific research objectives are to:

- Investigate and report the relationship between food colour and consumer perception;
- Investigate and report the relationship between food background (including food packaging and food crockery) colour and consumer perception;
- Consider potential differences between these colour-perception associations;
- Review different food colourants that could be applied to food production; and
- Explore real-life cases in the food market and analyse the reasons behind their success and failure.

This paper starts with an initial literature review that delivers a brief overview of the findings from a number of fields, including the food processing field, the psychology field, the consumer behavior field, and also the brand management field. The systematic literature review (SLR) technique proposed by Durach, Kembro, and Wieland (2017) is then introduced, and finally the results are presented and discussed[1].

Initial Literature Review

Food Colouring and Food Packaging Processes

[1] In both the initial and systematic literature reviews, no distinction is made between the papers surveyed on the basis of the quality of the methods used or the quality of the journals in which the findings were published. Given the limited objectives of this project, all peer-reviewed studies were given equal standing. A reviewer has reminded us that research in both perception and in food choice is not straightforward, and since some of the papers reviewed are several decades old, some of this literature could be classed as less reliable. The media reports cited were used to provide context and information about the case studies.

Food colouring

During the process of food production, food colourants are sometimes added to enhance the exterior attractiveness of a given food. They can offset unpleasant characteristics (Martins, Roriz, Morales, Barros and Ferreira, 2016) possibly caused by other food production processes. On top of that, they can also be used to maintain a food item's flavor, quality, safety, organoleptic properties, and customer satisfaction (Amchova, Kotolova and Ruda-Kucerova, 2015; Martins et al., 2016).

According to the United States Food and Drug Administration (FDA), a food colourant is any substance, dye, or pigment added to a food that is able to impart colour either by itself alone, or through reactions with other substances (FDA, 2018). Traditionally, the majority of food colourants used in the food industry were synthetic. However, consumers are now demanding more natural colourants with less side effects and toxins. As a response, food companies seek out natural food colourants derived from fruits, leaves, flowers, and plants. A popular colourant that is widely used is anthocyanins (Martins et al., 2016), which imparts red, blue, and purple colours under different environments.

Food packaging

The main purpose of food packaging is to carry the food/drink item and to protect it from potential hazards during storage and distribution (Fellows, 2009). In order to achieve this, packaging materials have to be carefully selected. Fellows (2009) summarized seven factors that food companies should consider when selecting packaging material. That is, for a material to be effective in fulfilling its main purposes, it should be light-restricted (or transmitted depending on product requirement), low in thermal-conductivity, moisture-exchange controlled, gas permeable (or impermeable depending on product requirement), greaseproof, contaminant-resistant, strong, and lastly, tamper-evident/resistant.

On the other hand, packaging is also often used by food businesses as a marketing tool. Packaging can be communicative, acting as a cue for its content (Fellows, 2009), as well as establishing a brand message.

How Do Colours Affect Consumer Perceptions and Decisions?

Food and drink colours

Over the years, researchers from different fields have contributed to the study of the relationship between colour and food. One of the earliest and influential studies was Maga (1974), who pointed out the natural correlation between the colour red and the sweetness taste, since a majority of fruits turn red when they are ripe. A similar correlation applies to the colour green and sourness, as unripe fruits are often green in colour. Johnson and Clydesdale's (1982) results also agreed with these aforementioned correlations. They found that sweetness is more easily perceived when red solutions are given to participants compared to uncoloured solutions. These lead to a conclusion that it is plausible for food companies to alter their products' perceived tastes without actually altering their production formulae.

Food packaging/background colours

Marketers have been experimenting with different elements in food packaging or branding to attract target customers. Particular interest has been put on how the 'colour' element of a food package influences product acceptability as well as consumers' purchase intention (e.g. Costell, Tárrega and Bayarri, 2010; Martins et al., 2016). When applied on packaging, colour does not seem to affect consumer perception much on the taste/flavor of the food/drink product per se, rather, it serves as an informative cue for consumers. For instance, without actually seeing or tasting an item, consumers see a red-coloured packaged item as less healthy than an identical item packed in blue (Huang and Li, 2016). On the other hand, the use of green labels on a food package is associated with healthfulness (Temple et al., 2011). In addition, when a dark colour is used, consumers tend to associate it with 'heaviness', which is then further associated with 'heavy in calories', affecting its perceived healthfulness (Mai, Symmank and Seeberg-Elverfeldt, 2016). Therefore, food companies have to consider carefully before they decide on a packaging colour as it is likely to be associated with the acceptability of the product itself.

How Do Food Businesses Choose Their Colours?

With the use of different colours, brands can differentiate themselves from their competitors (Labrecque and Milne, 2012). For instance, Coca-Cola and Pepsi are two major competitors in the soda industry, and they each carry a distinct and representative colour – red and blue. This way, consumers are less likely to confuse them with one another. With colour, businesses can also form a desirable visual identity, as well as maintain strong relationships with their target audience (Labrecque and Milne, 2012). It has been asserted that there is a systematic relationship between colour and emotions (Levy, 1984). For instance, yellow is associated with cheerfulness as it elicits feelings of optimism and friendliness (Clarke and Costall, 2007; Fraser and Banks, 2004; Levy, 1984). On the other hand, black is associated with glamour and sophistication (Fraser and Banks, 2004). Although red can be seen as a cue for unhealthy food, it stands for strength and excitement (Clarke and Costall, 2007; Fraser and Banks, 2004) when used in a branding context. When given the chance, consumers tend to pick consistent colour-emotion pairings (Levy, 1984) such as black and sophistication instead of red and sophistication, suggesting that these pairings may have been firmly established due to previous social signals received by the consumers. Hence, marketers should take into account all possible information when designing a brand colour, as inconsistent brand image may be formed due to the use of inappropriate colours.

Overview

While the initial literature review shows that a considerable amount of work has been done on the role of colour in food demand, across a number of different disciplines, that body of work has not been systematically organized into major theme areas. The systematic literature review (SLR) technique proposed by Durach, Kembro, and Wieland (2017) is one way of achieving this categorization.

Method

Traditionally, SLR was only adopted in the field of medicine (Durach et al., 2017). More recently, this method of reviewing literature can be seen in various fields, including the field of supply chain management (SCM). In order to be representative of and appropriate in the field it is used in, SLR guidelines need to be adjusted accordingly. For the overall convenience of the SCM discipline, Durach et al. (2017) came up with a SLR paradigm exclusively for SCM, which was applied to this project. The sequential steps of this method are as follows:

Defining the project aim

This step focuses on investigating whether previous findings can contribute to real-life situations. It is fundamental to develop this initial aim for subsequent steps.

Establishing research criteria (both inclusion and exclusion)

This step sets the inclusion and exclusion criteria. The criteria chosen can evaluate if a study is able to provide information about the research question. In order to obtain a broader overview of findings, it is important to note that other authors' choices of research method should not lead to an exclusion of their studies. Relevant journals, such as Appetite, Critical Reviews in Food Science and Nutrition, Food Chemistry, Food Quality and Preference, and Journal of Food Science, were given additional attention. A list of keywords was initially created, and then adjusted. The refined list of keywords include 'food colour', 'taste perception', 'flavour perception', 'food packaging colour', 'consumer behaviour', 'brand image', and 'colour psychology'. Combinations of them were used accordingly.

Reviewing potentially relevant literature

This step covers all aspects of the initial literature review, including their limitations. This can guide the next step, where a subset of the papers has to be selected. Upon the discovery of potential papers, their titles and abstracts were examined.

Narrowing down initial research to applicable samples

This step excludes irrelevant studies after examining beyond what is demonstrated in their titles and abstracts. Studies with irrelevant findings outside the scope of food colour and consumer perception were eliminated. After the exclusion of a number of papers, the research process was once again conducted, in order to gather sufficient useful papers.

Synthesising the studies

This step refines the proposed aim with information from the selected samples. The 'in what circumstances', 'when', and 'for whom' factors of the project have to be considered too. Studies that are related or belong to the same field were categorised, and four main categories were developed: 'Food Colour', 'Food Background Colour', 'Food Colourant', and 'Marketing and Case Studies'. The final set of studies contains 92 papers from various journals. They are listed in the Appendix.

Reporting SLR results and their market implications

This step presents the results alongside propositions that describe temporal, contextual, and conceptual elements. How these results could be implemented in the real world is also discussed.

Results and Discussion

Colour as a Visual Cue

People do not choose one food over another based only on its taste or smell, but on its visual quality too (Stillman, 2002). Chronologically, a product's appearance (especially its colour) is often the first element that consumers base their judgements on, and it can interact with gustatory, olfactory, and textural senses to influence a product's overall acceptability (Bayarri, Calvo, Costell and Durán, 2001; Dubose, Cardello and Maller, 1980). It can also trigger the fastest response (Swientek, 2001). Sometimes, this visual cue can even outweigh people's gustatory and olfactory senses when it comes to flavour perception (Garber, Hyatt and Starr, 2000; Piqueras-Fiszman, Alcaide, Roura and Spence, 2012). As a visual cue, the colour of a food/drink product can affect the product's aesthetics and sensory characteristic (Clydesdale, 1993). Moreover, the colour of a food can act as a safety cue by providing information about whether or not this food is safe to be consumed (Clydesdale, 1993; Wheatley, 1973).

Belief and Flavour Perception

If a person believes that a particular food will taste different because it has a different colour, it is likely that the difference in taste will in fact be experienced when that food is consumed. Levitan, Zampini, Li, and Spence (2008) did an experiment in the United Kingdom to test whether this is the case. In their experiment, students were given three different coloured Smarties, red, green, and orange, where the former two Smarties have identical flavour (i.e. milk chocolate) and the latter one has an additional orange flavour. They discovered that when participants have a belief that red and green Smarties differ in flavours (when in reality they do not), they are more likely to report such 'difference'.

On the other hand, Bayarri et al. (2001) carried out an experiment with four different flavoured drinks. They found that colours of peach, orange, and berries drinks impact subjects' perception of those drinks' typical fruit flavours, likely due to the expectations formed based on the colour-flavour associations the subjects have for those fruits.

Food Colour and Its Associations

People begin to associate certain acceptable food colours with perceptions such as sweetness, acceptability, and pleasantness in their cognitive development as early as at birth (Clydesdale, 1993), and these associations are strengthened with repeated exposures (Levitan et al., 2008). The stronger these associations (particularly the one between colour and flavour), the more impact the colour exerts (Delwiche, 2004).

Food colour and product acceptability

Dubose et al. (1980) stated that when the colour level of certain commercial beverages decreases, consumer's overall acceptability of the products is reduced, and this reduction cannot be compensated by an increase in flavour level alone. Furthermore, Johnson and Clydesdale (1982) reported that when the red colour of a cherry-flavoured beverage is too dark, it is consistently judged to be less pleasant. This is likely due to the fact that the intensity of the colour has exceeded the participants' expectation of a desirable cherry colour. It may seem that people tend to prefer food/drink colours that match with what they have experienced before, and can be retrieved from their memory (Wei, Ou, Luo and Hutchings, 2012).

In another study carried out by Wheately (1973), participants were served a dinner with blue steak, red peas, and green fries in a colour-masked condition. When lighting was resumed to normal condition during the meal, some participants felt so unwell that they had to interrupt the experiment. Furthermore, Maga (1973) demonstrated that although people have a clear preference for dark chips (which have an extended period of storage) when they are blindfolded, they always choose regularly coloured chips when given a visual option.

In addition, when food products such as yogurts are offered in a variety of colours, flavours and textures, consumption of them increases. However, this increase in intake is eliminated when different yogurts are offered in a single colour (Rolls et al., 1981). This increase in energy intake when a variety of food choices are presented is also supported by Levitsky, Iyer, and Pacanowski (2012). They further proposed the three underlying mechanisms for this behaviour, namely curiosity, boredom, and attribute satiation.

They explained that there are two types of boredom (Zandsra, Weegels, Van Spronsen and Klerk, 2004) that may have contributed to people's variety-seeking behaviour. The first type is a neural/physiological boredom with the food product per se, which results in a reduction in the actual liking of the food's attributes; whereas the second type is a cognitive boredom, which is boredom with the concept of the food, resulting in a reduction in the desire to repeatedly consume certain food. This is demonstrated clearly by a previous experiment where participants' pleasantness ratings are significantly lower when they repeatedly consume Smarties only in one colour, even though this colour is their favourite (Rolls, Rowe and Rolls, 1982). This suggests that when food companies provide their consumers with products served in a variety of colours, this can create an illusion that there are more availabilities in the market, and that consumers will have the autonomy to choose from them, leading to a potential increase in sales.

Food colour and flavour identification

Hall (1958) evaluated subjects' flavour identification of sherbets in different colours (whether it be an appropriate or inappropriate match with the flavour). He noticed that when sherbet is uncoloured or in white, people are not able to correctly identify any of the flavours tested (i.e. lime, lemon, grape, orange, pineapple, and almond). In addition, when these sherbets are miscoloured, people's flavour identifications are adversely affected. For example, when lime-flavoured sherbet is purple in colour, only 47 per cent of people (instead of 75 per cent when coloured green) correctly identified the lime flavour.

DuBose et al. (1980) observed similar results in their study on fruit beverages, where the beverages are coloured either appropriately (e.g. red-coloured cherry-flavoured beverage) or inappropriately (e.g. orange-coloured cherry-flavoured beverage). They found that people often misidentified flavours of the beverages when they are of inappropriate colours, and that their flavour responses tended to be misguided by the colours. For instance, people frequently misidentified an orange-coloured cherry-flavoured beverage as having an orange (or apricot) flavour, and a green-coloured cherry-flavoured beverage as having lime/lemon flavour.

This is supported by a later study by Stillman (1993), where he tested raspberry and orange flavoured beverages coloured red, orange, or yellow. He found colour has a significant effect on flavour identication, and that unusual combinations of colour and flavours reduce identification of both flavours. It is then not surprising that Christensen (1983) reported that typical coloured foods are perceived to have more intense flavour and aroma, and are deemed to be better in quality. They are also liked better, likely due to the concept of 'perceptual fluency', which explains when congruent cues are presented, they are more easily processed (Reber, Winkielman and Schqartz, 1998). Another similar concept would be the theory of disconfirmed expectations, which states that when a product does not taste like what you expect it to taste, you dislike the consumption experience more (Piqueras-Fiszman and Spence, 2012; Schifferstein, 2001; Velasco et al., 2016).

In the more recent Smarties study by Levitan et al. (2008), participants who were blindfolded could not accurately discriminate orange Smarties (despite the additional orange flavour) from the other Smarties. This further strengthens the proposition that colour plays an important role in flavour identification.

On the other hand, in terms of taste perception, Maga (1974) did an experiment to investigate the influence different colours have on people's ability to detect basic taste thresholds (i.e. sweet, sour, salty, and bitter), He found that for both yellow and green sour solutions, the sour concentration has to be significantly higher than the control for people to detect the sourness. This is also true for bitter solutions in these two colours. Moreover, red bitter solution requires the highest bitter concentration for the taste to be detectable. These results suggest that people do not associate yellow and green with sour, nor yellow, green and red with bitter. Furthermore, yellow is not associated with a sweet taste, but green-coloured sweet solution is detectable at a significantly lower concentration than the control, indicating an association between green and sweetness. In terms of saltiness, the author noted that people do not have a general colour association, possibly because salty foods can be of various colours such as yellow in potato chips and green in pickles, thus people's judgements cannot be guided by previous learning experience.

Food colour and taste/flavour perception

It has been found that the addition of red food colourant to sucrose solutions (either unflavoured or flavoured with cherry or strawberry flavours) increases the perceived sweetness of these solutions (Johnson and Clydesdale, 1982; Johnson, Dzendolet and Clydesdale, 1983; Johnson, Dzendolet, Damon, Sawyer and Clydesdale, 1982). However, Frank, Ducheny, and Mize (1989) recreated the strawberry sucrose solution study and did not find a significant effect of red dye on the solution's perceived sweetness. Instead, they found that odour may play a major role in altering the solutions' sweetness.

To further investigate this difference in findings, Velasco et al. (2016) conducted a large-scale experiment in the United Kingdom, with participants of various backgrounds (e.g. Africa, Asia, Europe, North America etc.), to specifically test if the colour red has a cross-cultural association with sweetness. Participants in this study were asked to choose a drink that looks 'sweetest' from images containing six different coloured drinks. Their result reveals that red indeed is the primary response for sweetness.

A possible explanation of this was proposed by Maga (1974), which states that the association people have between red and sweetness is a natural correlation. The majority of fruits ripen and their exterior colours change. This change usually goes from green to yellow, then to red. This ripening process is also mentioned by Schifferstein, Howell, and Pont (2017). People observe this natural change in fruit colours and may have unconsciously built a colour-taste association.

To contribute to this field, Roth, Radle, Gifford, and Clydesdale (1988) observed a significant colour-taste interaction between yellow colour and sweetness when the colour was added to lime/lemon flavoured beverages. Bayarri et al. (2001) also reported a significant colour-sweetness relationship for orange drink (but not for peach, kiwi, and berries drinks) with their experiment. They explained this result by suggesting that because orange drink is the most frequently consumed among all the fruit drinks, subjects are more able to relate its attributes (in this case its colour) to its taste.

If a subject's knowledge about the test sample plays a role in their perception of the sample, then it would be reasonable to investigate if it is possible that colour exerts an effect on experts of a certain food/drink but not on untrained consumers. In fact, Pangborn, Berg, and Hansen (1963) reported that when white wine is coloured pink (to resemble pink wines such as rosé), wine experts perceived it to be sweeter than its clear counterpart, whereas untrained panels found no difference. Again, the knowledge of the wine experts may have led them to perceive such difference, because pink wines in general have a higher sugar content. Nevertheless, it has to be taken into account that frequently exposed colour-taste associations may have an effect of raising people's taste threshold (Maga, 1974). A summary of the colour-taste associations mentioned above is provided in Table 1.

Clydesdale (1993) proposed that if the addition of certain food colourants can in fact enhance sweetness perception, it can be incorporated into food companies' production processes to potentially reduce the use of expensive ingredients. This can also benefit consumers who are health-conscious, as they experience similar sweetness perception with a product that is lower in sugar content.

Table 1. Summary of the relationship between different colours and their flavour/taste responses

Colour	Flavour/Taste Perception	Author
Red	Sweetness	Johnson and Clydesdale, 1982; Johnson et al., 1982; Johnson et al., 1983; Velasco et al., 2016
Yellow	Sweetness (in lime/lemon flavoured drink)	Roth et al., 1988
Orange	Sweetness (in orange drink)	Bayarri et al., 2001
Pink	Sweetness (in wine, when tasted by experts)	Pangborn et al., 1963

Food colour and taste/flavour intensity

In Dubose et al. (1980)'s experiment, they observed that the perceived flavour intensity of both orange and lemon beverages increases as their colour levels (i.e. orange and yellow respectively) increase, and this was found even in coloured but flavourless samples. Johnson and Clydesdale (1982) also observed a similar correlation between colour intensity and flavour intensity. In particular, when cherry-flavoured drinks are presented in five different red intensities (ranging from colour 1 to 5, lightest to darkest), colour 5 (i.e. the darkest) is consistently rated as the sweetest among the samples with between 2.8 per cent and 5.3 per cent sucrose concentration. The authors further discovered that if the sucrose content for colour 3, 4, and 5 solutions is decreased by 1 per cent, perceived sweetness will be enhanced by 2.5 per cent by increasing colour intensity from colour 3 to 4, and over 10 per cent from colour 3 to 5.

This phenomenon is supported by two other more recent studies. Bayarri et al. (2001) stated that when orange drink has a more intense colour, it has a more intense perceived sweetness. They explained this finding with participants' expectation on the use of riper (thus sweeter) ingredients. Wei et al. (2012) found similar result with their on-screen study, where orange juice with a highly saturated orange colour is expected to have a stronger orange flavour.

When it comes to beer, a similar trend has also been reported. Guinard, Souchard, Picot, Rogeaux, and Sieffermann (1998) put forward that when beer products have a stronger brown colour, they are perceived to be stronger in taste.

Generally, perceived flavour intensity tends to increase with colour intensity. That is, vivid colours can arouse stronger flavours or tastes than paler counterparts (Wei et al., 2012).

Food colour and thirst-quenching characteristic

In terms of other perceptions brought out by the colour of certain beverages, one study reported that people expect both brown and clear fruit-punch flavoured beverages to satisfy their thirst better, comparing to other coloured beverages (Clydesdale, Gover, Philipsen and Fugardi, 1992). These researchers suggested that the thirst-quenching expectation of the brown colour may be a learned association of such colour with cola. Similarly, clear beverages remind people of water, and hence are expected to be thirst-quenching. Zellner and Durlach (2003) supported the clear colour association with their study, where they tested the actual experienced refreshingness of clear and coloured beverages of three different flavours (i.e. lemon, mint, and vanilla), and found that the clear versions of all beverages are rated as more refreshing. However, when they tested the same beverages in brown colour, these beverages are perceived to be less refreshing (less pleasant even), contradicting what the subjects in Clydesdale et al. (1992)'s study expected. These authors further proposed that liking and refreshment may be correlated. That is, when a beverage is refreshing, it is liked better. Guinard et al. (1998)'s experiment produced results that agreed with Zellner and Durlach (2003), but not with Clydesdale et al. (1992). Their experiment focused on the thirst-quenching character of beer, where they found that the browner the beer, the less quenching it is rated. This may be due to the general associations the subjects have for brown and less refreshing, more bitter, and stronger, beers.

Food colour and smell perception

When it comes to the olfactory sense, colour also exerts an influence. When two equally concentrated solutions (one coloured and the other colourless) are presented, the coloured solution is perceived as having a more intense smell (Zellner and Kautz, 1990). Interestingly, unlike flavour/taste perception, olfactory perception is not affected by the appropriateness of the colour. For example, Zellner and Whitten (1999) coloured the same methyl salicylate solutions green and brown respectively, and tested their perceived smell intensity. Both green and brown solutions, whether they are labelled as wintergreen or as root beer, are influenced by the added colours on their smell intensity. This suggests that while the presence of colour is needed to enhance smell intensity, the appropriateness is not as much. Nevertheless, it has to be noted that the appropriateness of colour, although has limited influence on olfactory perception per se, can affect the likeability of the solution - appropriately coloured solutions are judged to be more pleasant than inappropriately coloured ones (Zellner, Bartoli and Eckard, 1991).

The above experiments all focused on an orthonasal perspective, which is when a smell is perceived through the nostrils. Zellner and Durlach (2003) included a retronasal perspective (i.e. smell perceived from the mouth) in their study, and concluded that colour does not have a significant effect on odour intensity perceived retronasally as it does orthonasally.

Food Colouring and Food Colourants

Since the natural colours of foodstuff tend to deteriorate during storage and processing, food colourants have always been used by food companies as a tool to offset this deterioration, to correct food's colour variation, as well as to enhance food's natural colours (Martins, Roriz, Morales, Barros and Ferreira, 2016).

In addition, as discussed above, the colours of the food can also exert influences on consumers' perception. It then seems sensible and beneficial for food companies to incorporate different colours in their food product design and production processes. However, it has to be considered that when a food/drink product is coloured with bright or unnatural hues, especially with synthetic food colorants, many consumers would suspect it to be harmful (Burrows, 2009). In fact, several synthetic food additives that were allowed in the market before are no longer available, precisely due to their harmful consequences. Some of these additives are found to be toxic and carcinogenic when consumed at medium to long terms and carry undesirable side effects (Amchova, Kotolova and Ruda-Kucerova, 2015).

Despite this, there are still some synthetic food colourants in the market that are considered safe and thus are allowed to be added into food/drink products, as long as they follow the acceptable daily intake guidelines. Some of these currently available colourants include (Bonan, Fedrizzi, Menotta and Elisabetta, 2013; Gu et al., 2015; Minioti, Sakellariou and Thomaidis, 2007):

- Brilliant blue FCF, which is used in coloured beverages, candies, jellies etc.
- Allura red AC, commonly used in coloured soft drinks
- Quinoline yellow, often used in fruit and vegetable juices
- Green S, used in canned peas, mint sauce etc.
- Titanium dioxide, used in confectionary, cheese etc.

Among these colourants, blue colourants are believed to be the least dangerous, followed by yellow, green, and white, and then by red and orange (Martins et al., 2016).

Because of the safety concerns associated with synthetic food dyes, consumers are now demanding natural colourants derived from food pigments. It is also believed that these natural pigments carry some health benefits and can even act as antioxidants (Carocho, Barreiro, Morales and Ferreira, 2014). Nonetheless, they are still not routinely employed by food companies because they are often more expensive, less stable, and have a limited range of hues (Rodriguez-Amaya, 2016). The four main groups of natural pigments and their details are listed below:

Chlorophyll

Chlorophylls *a* and *b* have been found in medium-ripened Jalapeño peppers (Cervantes-Paz et al., 2014), apples (Delgado-Pelayo, Gallardo-Guerrero and Hornero-Méndez, 2014), kiwifruits (Benlloch-Tinoco et al., 2015), and other vegetables (Sánchez, Baranda and de Marañón, 2014).

Natural pigments are often susceptible to food processing, especially heat treatment, and this is true with chlorophylls. It has been demonstrated that conventional heat processing of kiwi puree can lead to up to 100 per cent of chlorophyll loss (Benlloch-Tinoco et al., 2015). The authors also demonstrated that although a microwave process is not as damaging to kiwi puree, it can still decrease its chlorophyll level by at least 42 per cent. Moreover, it has been shown that when high pressure and high temperature processes are used together, both chlorophylls are degraded (Sánchez, Baranda and de Marañón, 2014). Specifically, when temperature reaches 117°C, both chlorophylls *a* and *b* (even though *b* tends to be more stable) are highly degraded.

Currently, the only two approved chlorophyll colourants according to the United States FDA are chlorophyll complexes and chlorophyllins (FDA, 2017).

Carotenoid

Although the majority of commercial carotenoids used currently, such as β-carotene and canthasanthin, are chemical synthesised (Rodriguez-Amaya, 2016), they are extracted from natural plants like Asian gac fruits (Chuyen, Nguyen, Roach, Golding and Parks, 2015), *Canna indica* flowers (Srivastava and Vankar, 2015), and tomatoes (Poojary and Passamonti, 2015).

Similar to chlorophylls, carotenoids are susceptible to food processing. Oxidation and geometric isomerisation are reported to be the major causes of carotenoids alterations (Rodriguez-Amaya, 2015).

In order to optimise carotenoids extraction, different methods have been proposed. For instance, ultrasonication is proved to be able to extract natural pigment from *Canna indica* flowers efficiently (Srivastava and Vankar, 2015). In addition, microencapsulation (in this case, spray-drying) of gac oil results in higher lycopene and β-carotene contents in a red-yellow powder (Kha, Nguyen, Roach and Stathopoulos, 2014). Genetic engineering, including gene transferring and recombinant technology, has also been introduced to the market (Shumskaya and Wurtzel, 2013), although it still requires appropriate investigations.

Anthocyanin

Anthocyanins can be sourced from a range of red-purple fruits and vegetables, including berries, purple sweet potato, and red cabbage (Rodriguez-Amaya, 2016). The colour of anthocyanins is highly dependent on the pH, as well as its stability. Light, temperature, oxygen, proteins, enzymes, and the presence of other flavonoids are other factors that affect its stability (Rodriguez-Amaya, 2016). Aside from water extraction, which is deemed to be environmentally-unfriendly, ultrasound and pulsed electric fields can be used for anthocyanin extraction. They are also found to increase extraction efficiency in both plum and grape peels (Medina-Meza and Barbosa-Cánovas, 2015). Ohmic heating-assisted extraction has also been proposed, and has been tested on black glutinous rice bran with desirable result (Loypimai, Moongngarm, Chottanom and Moontree, 2015).

Due to its instability and reactivity, the FDA approved anthocyanin additives are grape colour and skin extracts only (FDA, 2017).

Betanin

Beetroot has always been deemed to be the best and only source of betanin, and its powder form is the single additive approved by FDA (FDA, 2017). With this limitation, alternative sources have been investigated. Ulluco (Cejudo-Bastante, Hurtado, Mosquera and Heredia, 2014) and matured Malabar spinach (Kumar, Manoj, Shetty, Prakash and Giridhar, 2015) are reported to be possible sources of betanin. When Malabar spinach extract is used as a colourant in ice cream, 87 per cent of the pink-purple colour is retained in the ice cream even after six months of storage (Kumar, Manoj, Shetty, Prakash and Giridhar, 2015). In terms of betanin degradation, hydrolysis during storage is found to be the major cause (Vergara, Saavedra, Sáenz, García and Robert, 2014). Synthetic and natural colourants that are currently used in the food market and the colours that they can generate can be seen in Table 2.

Table 2. Approved synthetic and natural colourants and their colours

Synthetic Colourants	Natural Alternatives	Colours	Authors
Brilliant Blue FCF	Anthocyanin	Blue (sometimes red and purple)	Bonan et al., 2013; Rodriguez-Amaya, 2016
Allura Red AC	Betanin	Red	Bonan et al., 2013; Cejudo-Bastante et al., 2014; Kumar et al., 2015
Quinoline Yellow	Carotenoid	Yellow	Bonan et al., 2013; Chuyen et al., 2015; Srivastava and Vankar, 2015; Poojary and Passamonti, 2015
Green S	Chlorophyll	Green	Minioti et al., 2007; Cervantes-Paz et al., 2014; Delgado-Pelayo et al., 2014; Sánchez et al., 2014
Titanium Dioxide	N/A	White	Gu et al., 2015

Background Colour and Its Associations

Crockery colour and consumer behaviour

The colour of the crockery that a food is served with has been shown to exert an influence on consumer behaviour. For instance, people tend to eat less snack food (e.g. pretzels) when it is served on a red plate, rather than on a blue or white plate (Genschow, Reutner and Wanke, 2012). This is interesting because the authors found that food on a red plate is rated to be more appealing, appetising, and attractive, and is liked more than the same food on a white plate; while it does not seem to differ from the blue plate. Therefore, the authors ruled out the possibility that this decrease in consumption is due to food being less appealing on the red plate. Instead, they argued that this observation is likely due to the natural predisposition of the colour red as a warning signal, thus giving rise to participants' avoidance behaviour. This was supported by Bruno, Martani, Corsini, and Oleari (2013), where they also reported a reduction in food consumption when samples are served on a red plate, even though they are all rated similarly in likeability.

Moreover, it has been found that crockery colour can even influence the perceived flavour intensity of certain food. Piqueras-Fiszman et al. (2012) conducted an experiment where they presented two samples of the same strawberry mousse on a black plate and a white plate, and required their participants to taste one sample, rate its flavour intensity, and then taste the other. They reported that when mousse is served on a white plate, it is rated 1.28 points higher (on a 9-point scale) in flavour intensity than when served on a black plate. The authors explained this by pointing out a possible visual illusion, that is, contour contrast (Hutchings, 1994), that the participants may have experienced when a pink mousse is contrasted by the white plate, resulting in a pinker-looking mousse and a sweeter taste perception.

Background colour and consumer perception

When it comes to the relationship between background colour and items that are presented in front of it, one research on background colour has demonstrated that all foreground colours (in this case the food/drink product) are enjoyed when presented on a background with cool colours such as blue; whereas only foreground with cool colours are liked when presented on a warm background such as orange (Schloss and Palmer, 2011). This is similar to a phenomenon named 'simultaneous contrast' (Hutchings, 1994; Lyman, 1989), who reported that, for instance, the orange colour in a carrots is intensified when shown on a blue background. Nevertheless, when warm/cool background colours were tested by Schifferstein et al. (2017), they reported a different finding. They found that each fresh produce has its own optimal background colour which enhances its perceived attractiveness, and this colour is usually contrasting with the product in hue, chromaticness, and blackness. For example, the optimal background colour for a cucumber would be light orange, which has strong contrasts in both hue and blackness. This finding essentially disagrees with Schloss and Palmer (2011)'s finding. Schifferstein et al. (2017) also observed another phenomenon, where 3D objects seem to look more saturated when presented on colours with similar hues. And this more saturated colour is preferred by most people, as saturation of colours often decreases when food products deteriorate (Lee, Lee, Lee and Song, 2013). In fact, Schifferstein et al. (2017) found that when carrots are shown with an orange background, they are rated as most attractive.

Packaging colour and consumer perception

Packaging materials not only serve a protection purpose for the food products, but also form a coloured 'background' against which consumers evaluate fresh produce, as this background colour may affect the perceived colour of the food/drink products (Schifferstein et al., 2017). One of the first studies done on this topic was Cheskin (1957), in which he coined the phenomenon 'sensation transference'. In this study, he reported that when 15 per cent more yellow colour is added to the green on 7 Up cans, the drink is perceived to be significantly more lemony/limey in taste.

It has been observed that food/drink products packaged in vivid, highly saturated colours are often unhealthful, whereas those packaged in muted and less saturated colours are healthful (Mead and Richerson, 2018), Mead and Richerson (2018) performed an experiment on whether this frequent observation would lead to consumers establishing a psychological heuristic about vivid package colour equals food unhealthfulness. Indeed, they found that when people are asked to judge the healthfulness of nutrition bars and potato chips packaged in different colours, they perceive both foods as less healthful when packaged in vivid and highly saturated colours. One of the reasons these packaging colours for unhealthful foods are chosen by food companies is the connotation people have with them (e.g. red) and the feeling of excitement (Labrecque and Milne, 2012).

Furthermore, it has been argued that certain populations are more susceptible to this colour heuristic than others. For instance, consumers with restrained eating behaviour are significantly more likely to depend on package colour saturation when judging a food's healthfulness; whereas consumers with sufficient level of nutrition knowledge are less likely to be influenced by these vivid packagings (Mead and Richerson, 2018).

It has to be noted that although these colours, in particular red, can be exciting, it can also bring out the same avoidance behaviour mentioned before. For example, when red and blue packages are shown on a screen, subjects rate the red package to be less healthful than the blue package, and the purchase intention for the red package is lower (Huang and Lu, 2016). This effect is also seen on red labels on a food package (Levy, Riis, Sonnenberg, Barraclough and Thorndike, 2012). De Bock, Pandelaere, and Van Kenhove (2013) concluded that consumers generally perceive red as negative.

Researchers believe that there are certain packaging colours that are deemed to be appropriate for certain product categories (Spence, 2010; Wheatley, 1973). Even a subtle change in these colours can result in considerable emotional consequences, possibly due to a disconfirmation of expectation (Piqueras-Fiszman and Spence, 2011). As a result, when an incongruent package colour is paired with a flavour, consumers' reaction times are longer, and it also leads to more incorrect responses regarding the flavour (Piqueras-Fiszman and Spence, 2011). This package colour influence on flavour is so strong that it even overrides the brand name effect, especially for food/drink products that are bought and consumed impulsively (Piqueras-Fiszman and Spence, 2011).

Crossmodal Correspondence

According to what has been summarised above, it appears that there are some general associations that people hold between seemingly unrelated sensory attributes of food products (Piqueras-Fiszman et al., 2012), and these associations are strengthened with frequent and repeated co-occurences (Elliot, Maier, Moller, Friedman and Meinhardt, 2007).

Cultural differences

Cultural specificities exist because different colour-flavour associations are established in different parts of the world (Wheatley, 1973). For instance, lemons found in Europe are usually yellow in colour, whereas those found in Colombia are dark green (Demattè, Sanabria and Spence, 2006). This undoubtedly sets a difference between the flavour association that would have been formed in Europe and one that would have been formed in Colombia.

In addition, Velasco et al. (2016) presented dishes in different colours (i.e. brown, green, red, and white) to Mexican and Brazilian participants and asked them to match the dishes to their most suitable tastes (i.e. sweet, sour, salty, and bitter). They found that red is most frequently associated with sweet in both cultures, except white is also associated with sweet by Mexicans. Instead, Brazilians matched white with salty, whereas Mexicans chose brown. They did not find any colour-taste association for bitterness in both cultures.

The colour red has been argued to act as a signal for danger when used as a background colour, and this holds true in many cultures. However, in the Chinese culture, red is associated with good luck and prosperity. Schifferstein et al. (2017) argued that this association may actually increase the consumption of food when presented against a red background, instead of decreasing it.

Age differences

To explore the possible perception differences in different age groups, Philipsen, Clydesdale, Griffin, and Stern (in press) carried out an experiment on this area of focus. They formulated 15 beverages differing in flavours, sucrose levels, and colours. This experiment was performed on two distinct groups of subjects, one consisting of elders aged over 60, and the other consisting of teenagers and young adults aged 18 to 22. They reported a trend (although not significant) for enhanced consumption as colour intensity increases in the elderly group but not in the college-age group. Higher flavour quality and intensity are again perceived by the elderly group when beverages are more intense in colour, whereas this trend is not shown in the younger group.

Case Studies

According to the perceptual fluency concept and the theory of disconfirmation of expectations mentioned before, it is stated that when incongruent colour is used for a food product, consumers tend to like and accept it less. This was demonstrated in the real marketplace in 1993, when Pepsi and Coca-Cola both launched their respective clear version of soda, namely Crystal Pepsi (Figure 1) and Tab Clear (Figure 2), and failed (Triplett, 1994).

Figure 1. Crystal Pepsi

From *Picture: Pepsi,* by E. Scott, 2016, https://metro.co.uk/2016/06/30/rejoice-crystal-pepsi-is-finally-back-in-our-lives-5975742/.

Figure 2. Tab Clear

From *Tab Clear,* by L. Benedictus, 2016, https://www.theguardian.com/business/shortcuts/2016/jan/17/fizzled-out-a-history-of-coca-cola-flops

Interestingly, 7-Up's clear soda has been iconic, at least in the United States, since 1929. They initially chose to be clear so that they could be differentiated among their competitors (Burrows, 2009). At the time, one analyst proposed that the difference between consumers' reactions towards Pepsi, Coca-Cola, and 7-Up exists because the cola companies had spent decades convincing consumers that colas should be dark in colour (Anon, 1993). Therefore, when clear colas were introduced to the market, consumers found them bizarre and rejected them. Moreover, Burrows (2009) suggested that this market failure may also be due to the fact that the clear colour suggested a taste that the actual colas did not provide. That is, when clear colas were introduced, consumers might have subconsciously expected a lemon/lime flavoured soda, but instead they tasted traditional cola.

In 2000, Heinz, a major condiment company in the food market, launched a 'Heinz EZ Squirt' line which provided a variety of ketchups in different colours to its consumers, specifically children. The green ketchup (Figure 3), in particular, was a huge success at the time. This led to more coloured ketchups (e.g. blue, pink, purple) being released into the market, making a considerable profit for Heinz. However, children lost their interests eventually, and adults had always preferred their ketchups in natural hues. Thus, in 2006, the line was discontinued and Heinz's green ketchup is no longer seen in the current market (Mancini, 2014).

Figure 3. Heinz EZ Squirt

From *EZ Squirt,* by K. Pang, 2015, https://medium.com/@kaeteepang/what-is-ez-squirt-ketchup-by-heinz-325d13bfb6e4

Nonetheless, sometimes this incongruency of color in food product can be a success in the food market. For instance, Burger King Japan launched a black burger made with charred bamboo buns and squid ink ketchup (Cook, 2012; Figure 4), and a red burger made with tomato powder buns and cheese (Nagata, 2015; Figure 5), in 2012 and 2015 respectively. These burgers helped Burger King to increase media attention by creating a shock factor with limited marketing budget (Velasco et al., 2016). This is an example of visible incongruency, where consumers can tell directly that there is a surprising factor present in the food. In this case, the incongruency only lies in the colour, because the flavours of both burgers are not rare flavours one finds in a burger (Velasco et al., 2016). This may explain one of the reasons why they were a success in the food market.

Another real-life example that challenges the disconfirmation of expectations is Walkers' potato chips. As early as in the 1960s, potato chips brands in the United Kingdom had always used green packaging for cheese and onion-flavoured and blue packaging for salt and vinegar-flavoured chips. However, in the 1980s, one of these brands, namely Walkers, confronted this convention by switching their packaging colours to blue (cheese and onion; Figure 6) and green (salt and vinegar; Figure 7). This switch led to an increase in sales of their salt and vinegar chips (McDermott, 2013). These then novel packaging colours successfully captured consumers' attention and benefited Walkers.

Figure 4. Burger King Black Burger

From *Overturning preconceptions: Burger King's kuro burger is made with bamboo charcoal and squid ink,* by W. Cook, 2012, https://www.dailymail.co.uk/news/article-2208321/Burger-King-black-burger-Japan-bamboo-charcoal-squid-ink.html

Figure 5. Burger King Red Burger

From *One of Burger Japan's new burgers, Aka Samurai Beef, comes with red buns and red cheese mixed with tomato powder, a beef patty and onion,* by K. Nagata, 2015, https://www.japantimes.co.jp/life/2015/06/17/food/burger-king-unveils-red-colored-burgers/#.XPOWQKYlGfQ

However, Garber et al. (2008) argued that this is not necessarily the case always. They proposed that a novel packaging colour translates into increased purchase only when this colour can be positively associated with a preferable product performance.

Figure 6. Walkers Cheese and Onion Chips

From *Cheese and Onion Walkers,* by A. Duggins, 2015, https://www.timeout.com/london/food-drink/28-corner-shop-crisps-ranked-worst-to-best

Figure 7. Walkers Salt and Vinegar Chips

From *Cheese and onion vs salt and vinegar: blue vs green!,* by J. Rodger, 2016, https://www.birminghammail.co.uk/whats-on/food-drink-news/walkers-crisps-makes-cheese-onion-12108260

Conclusion and Recommendations

Food businesses invest considerable time and money to discover ways to satisfy their consumer needs, hoping to establish consumer loyalty. Aside from a product's intrinsic properties, businesses also focus on extrinsic properties, one of which is colour. Colour can be implemented on different aspects of the food products, including directly changing or intensifying the colour of the food itself, adding to food packages as a design element, or being the colour of the crockery served with the food. When the colour element is appropriately employed, it is found to be able to change consumer perception, including product acceptability, flavour identification, taste/flavour perception, flavour intensity, as well as consumer behaviour.

It has been postulated that there are certain colour levels that consumers are used to, and find acceptable. When these colours are modified, consumer acceptability of the product will decrease, even if the flavour level is adjusted accordingly. Moreover, when more colour options are available in a product range, consumers tend to have an increase in consumption. This variety-seeking behaviour could possibly be explained by three mechanisms: curiosity, boredom, and attribute satiation.

In terms of flavour identification, it is shown that when incongruent color-flavour pairings are presented, people find it harder to identify the flavour of the product. Their responses are often misguided by the colour – if a lime flavoured sherbet is coloured purple, people will mis-identify it as grape flavoured.

There are some colours that are found to trigger certain taste or flavour perceptions. These colours include red, which seems to induce a taste of sweetness even in unflavoured samples; yellow, which brings out sweetness in lime/lemon flavoured drinks; and orange, which triggers sweetness perception in orange juice. It has been proposed that sometimes the knowledge of the taster also exerts an influence on flavour perception, because they can use the product's attributes to form a judgement based on previous experiences.

Interestingly, when the intensity of a food colour reaches a certain level, it starts to affect the food's taste/flavour intensity. This phenomenon is demonstrated by several previous studies. For instance, when a cherry-flavoured beverage is presented in five different red colour intensities, the darkest sample is perceived to be the most intense in sweetness.

The colour clear has been found to be more quenching than many other colours when used in beverages, likely due to the fact that it resembles water. On the other hand, brown has been found to be thirst-quenching in some cases, but not in others. This depends on the type of beverages being tested.

Currently, there are several synthetic colourants that are approved to be used in food. Some of them include: brilliant blue FCF, allura red AC, quinoline yellow, green S, and titanium dioxide. Nevertheless, due to their unpleasant side effects, natural colourants have been introduced to the market. Examples of them are: chlorophylls, carotenoids, anthocyanins, and betanin.

Background colours, including food packaging colour and crockery colour, have also been investigated. Generally, when red is used as a background colour, although it does not affect the likeability of the product, it triggers an avoidance behaviour in consumers. This may be due to the connotation that consumers hold between red and danger.

When cultural and age differences are taken into account, the colour element can be beneficial to several fields. For example, food companies can capitalise on this knowledge of colour-flavour association to potentially launch products with more intense perceived flavour using the same amount of seasoning, or products with the same perceived flavour intensity using less seasoning. This could be done by adding appropriate food colourants to their products to trigger consumers' taste/flavour perception. Furthermore, this would be especially beneficial for food companies that are trying to hold a 'healthy' image, as the reduced use of seasoning (e.g. salt and sugar) could be mentioned as a health claim on the packaging to attract target segment. One thing to note is that colourants added to food products should be sourced from natural origins in order to further strengthen the health claim.

Building on this point, the addition of appropriate colour in foods can also benefit consumers who are health-conscious. If a certain taste/flavour level can be induced by merely the use of food colourants, consumers can potentially maintain a healthier lifestyle which is low in sugar or salt.

Furthermore, the knowledge of the effects of colour on consumer perception could also be applied in the food packaging industry. Design companies could select their choice of colour when designing food packages based on this knowledge, with the aim to stimulate consumption or other desirable behaviours. This is important because food packaging is the first element that consumers interact with of the food product. If the packaging is able to capture consumer attention, it increases the chance that the product is purchased, and allows for further evaluation of it.

On the other hand, the potential for food companies to manipulate consumer perceptions to their disadvantage always exists, and given the continuing array of critiques from dieticians and public policy advocates, this potential may often be promoted to action.

Overall, colour can evidently be employed to a certain extent as a food element to add value to a number of food products and the companies that make them. Future studies are encouraged in order to broaden the horizon and strengthen the findings on this topic. Given the wide range of possible implications, perhaps one avenue for future research is to take a product-specific approach and investigate those implications in more detail.

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Appendix 1. Journal papers and news articles on the effects of colours as different food components

Authors	Year	Category/Association
Cheskin	1957	Food Background Colour
Wheatley	1973	Food Background Colour
Lyman	1989	Food Background Colour
Garber, Jr., Hyatt and Boya	2008	Food Background Colour
Costell, Tárrega and Bayarri	2010	Food Background Colour
Spence	2010	Food Background Colour
Piqueras-Fiszman and Spence	2011	Food Background Colour
Schloss and Palmer	2011	Food Background Colour
Temple, Johnson, Archer, LaCarte, Yi and Epstein	2011	Food Background Colour
Genschow, Reutner and Wanke	2012	Food Background Colour
Levy, Riis, Sonnenberg, Barraclough and Thorndike	2012	Food Background Colour
Piqueras-Fiszman, Alcaide, Roura and Spence	2012	Food Background Colour
Huang and Lu	2016	Food Background Colour
Mai, Symmank and Seeberg-Elverfeldt	2016	Food Background Colour
Schifferstein, Howell and Pont	2017	Food Background Colour
Mead and Richerson	2018	Food Background Colour
Hall	1958	Food Colour
Pangborn, Berg and Hansen	1963	Food Colour
DuBose, Cardello and Maller	1980	Food Colour
Rolls, Rowe, Rolls, Kingston, Megson and Gunary	1981	Food Colour
Johnson and Clydesdale	1982	Food Colour
Johnson, Dzendolet, Damon, Sawyer and Clydesdale	1982	Food Colour
Rolls, Rowe and Rolls	1982	Food Colour
Christensen	1983	Food Colour
Johnson, Dzendolet and Clydesdale	1983	Food Colour
Roth, Radle, Gifford and Clydesdale	1988	Food Colour
Frank, Ducheny and Mize	1989	Food Colour
Zellner and Kautz	1990	Food Colour
Zellner, Bartoli and Exkard	1991	Food Colour
Clydesdale, Gover, Philipsen and Fugardi	1992	Food Colour
Clydesdale	1993	Food Colour
Philipsen, Clydesdale, Griffin and Stern	1995	Food Colour
Guinard, Souchard, Picot, Rogeaux and Sieffermann	1998	Food Colour
Zellner and Whitten	1999	Food Colour
Garber, Jr., Hyatt and Starr	2000	Food Colour
Bayarri, Calvo, Costell and Durán	2001	Food Colour
Swientek	2001	Food Colour
Zellner and Durlach	2003	Food Colour

Delwiche	2004	Food Colour
Zandstra, Weegels, Van Spronsen and Klerk	2004	Food Colour
Demattè, Sanabria and Spence	2006	Food Colour
Elliot, Maier, Moller, Friedman and Meinhardt	2007	Food Colour
Zampini, Sanabria, Phillips and Spence	2007	Food Colour
Levitan, Zampini, Li and Spence	2008	Food Colour
Villegas, Carbonell and Costell	2008	Food Colour
Spence, Levitan, Shankar and Zampini	2010	Food Colour
Levitsky, Iyer and Pacanowski	2012	Food Colour
Wei, Ou, Luo and Hutchings	2012	Food Colour
Bruno, Martani, Corsini and Oleari	2013	Food Colour
Lee, Lee, Lee and Song	2013	Food Colour
Velasco, Michel, Youssef, Gamez, Cheok and Spence	2016	Food Colour
Maga	1973, 1974	Food Colour
Stillman	1993, 2002	Food Colour
Minioti, Sakellariou and Thomaidis	2007	Food Colourant
Burrows	2009	Food Colourant
Bonan, Fedrizzi, Menotta and Elisabetta	2013	Food Colourant
Shumskaya and Wurtzel	2013	Food Colourant
Carocho, Barreiro, Morales and Ferreira	2014	Food Colourant
Cejudo-Bastante, Hurtado, Mosquera and Heredia	2014	Food Colourant
Cervantes-Paz, Yahia, Ornelas-Paz, Victoria-Campos, Ibarra-Junguera, Pérez-Martínez and Escalante-Minakata	2014	Food Colourant
Delgado-Pelayo, Gallardo-Guerrero and Hornero-Méndez	2014	Food Colourant
Kha, Nguyen, Roach and Stathopoulos	2014	Food Colourant
Sánchez, Baranda and de Marañón	2014	Food Colourant
Vergara, Saavedra, Sáenz, García and Robert	2014	Food Colourant
Amchova, Kotolova and Ruda-Kucerova	2015	Food Colourant
Benlloch-Tinoco, Kaulmann, Corte-Real, Rodrigo, Martínez-Navarrete, Torsten Bohn	2015	Food Colourant
Chuyen, Nguyen, Roach, Golding and Parks	2015	Food Colourant
Gu, Hu, Guo, Jin, Wang, Oh, … Wu	2015	Food Colourant
Kumar, Manoj, Shetty, Prakash and Giridhar	2015	Food Colourant
Loypimai, Moongngarm, Chottanom and Moontree	2015	Food Colourant
Medina-Meza and Barbosa-Cánovas	2015	Food Colourant
Poojary and Passamonti	2015	Food Colourant
Srivastava and Vankar	2015	Food Colourant
Rodriguez-Amaya	2015, 2016	Food Colourant
Food and Drug Administration	2017, 2018	Food Colourant
Martins, Roriz, Morales, Barros and Ferreira	2016	Food Colourants

Levy	1984	Marketing and Case Studies
Triplett	1994	Marketing and Case Studies
Fraser and Banks	2004	Marketing and Case Studies
Clarke and Costall	2007	Marketing and Case Studies
Plassmann, O'Doherty, Shiv and Rangel	2008	Marketing and Case Studies
Fellows	2009	Marketing and Case Studies
Labrecque and Milne	2012	Marketing and Case Studies
De Bock, Pandelaere and Van Kenhove	2013	Marketing and Case Studies
McDermott	2013	Marketing and Case Studies
Mancini	2014	Marketing and Case Studies
Cook	2015	Marketing and Case Studies
Duggins	2015	Marketing and Case Studies
Nagata	2015	Marketing and Case Studies
Rodger	2016	Marketing and Case Studies