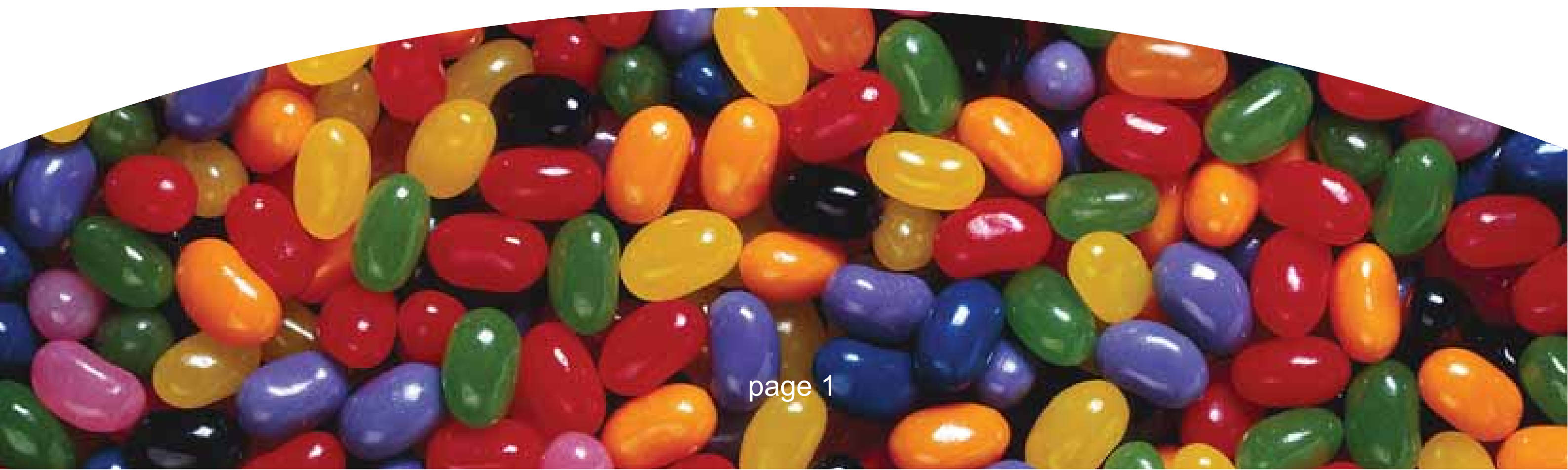
Food Standards Agency
food.gov.uk

Guidelines on approaches to the replacement of Tartrazine, Allura Red, Ponceau 4R, Quinoline Yellow, Sunset Yellow and Carmoisine in food and beverages

Summary

This guideline provides information on alternative colouring options for the reformulation of food and beverages, which currently contain one or more of the Southampton six colours (sunset yellow FCF (E110), quinoline yellow (E104), carmoisine (E122), allura red (E129), tartrazine (E102), ponceau 4R (E124)). There is a selection of naturally derived colours and colouring foodstuffs available to manufacturers, which produce colours in the same red, orange and yellow range as the Southampton six colours. Unfortunately, colours derived from natural sources are less stable than the synthetic colours they are replacing and therefore an understanding of the properties and the stabilities of these colours is crucial for successful replacement. The guide gives an overview of the different colour options available and the different factors that should be considered when approaching colour reformulation in a food or beverage product. In some applications particularly those with a long shelf life which are heated and/or exposed to light and oxygen, it is more difficult to achieve the right colour, particularly if an exact match for an existing colour is needed. Some examples of colours used to replace some of the Southampton six colours in confectionery, beverages and processed meat and fish products are included within the review.

Much help is available from food colour suppliers who are able to assist by not only offering samples of suitable colours but also technical advice as to which colours would be most suitable for a particular food application produced under particular manufacturing and packaging conditions with the required stability for the shelf life. It is recommended that food manufacturers work closely with colour suppliers, in order to get the optimum replacement colour for their product.



Contents

1: Introduction

The colour of food is important for consumers as it is the first characteristic to be noticed and one of the main ways of visually assessing a food before it is consumed. The perceived colour provides an indication of the expected taste of a food. If the flavour of a food product is inconsistent with the colour, the flavour can often be perceived incorrectly; for example an orange flavoured drink coloured green could be perceived to taste of lime.

Many raw foods such as fruit and vegetables have a bright attractive colour. However, the colour of some foods is reduced during food processing. Other foods such as confectionery items and flavoured soft drinks would be grey or colourless if colour was not added to them during the manufacturing process.

Colour has been added to food to enhance it for several hundreds of years. In the developing food industry of the late 19th century a wide range of synthetic colours were used, but issues over the toxicity of these additives led to the development of legislation controlling the types and quantity of these synthetic colours that could be added to food. There is now legislation controlling the use of colour additives throughout the world.

Some of these additive colours are made by chemical synthesis, which includes the Southampton six colours, and some are produced from naturally occurring sources such as plants, fruits and vegetables. In the European Union there is no legal distinction made between synthetic colours and those derived from more natural sources. All permitted colours have been tested for safety and given an E number for identification. Each colour has a specific purity criteria to which they must comply (set out in Commission Directive 2008/128/EC laying down specific purity criteria concerning colours for use in foodstuffs, enforced via Scottish Statutory Instrument 2009 No. 436 'The Food Additives (Scotland) Regulations 2009 (as amended) in Scotland or the relevant Statutory Instrument elsewhere in the UK **(see footnote *)**. In addition the conditions under which the colour can be used are laid down in EU Regulation 1333/2008 on food additives which, until Annex II is populated, applies the provisions of EU Directive 94/36/EC on colours for use in foodstuffs. These include:

- List of foodstuffs to which colour cannot be added or to which only limited colours can be added
- Colours with restricted food application.
- A list of colours approved for use in the EU
- Level of permitted colours for different food categories

*** The Food Additives (England) Regulations 2009 SI 2009 No. 3238, The Food Additives (Wales) Regulations 2009 SI 2009 No. 3378 (W.300) and the Food Additives Regulations (Northern Ireland) 2009 SR 2009 No. 416**

In recent years food containing synthetic colours has been increasingly avoided by consumers, partly due to an increasing trend to avoid foods containing artificial additives and a perceived link between the consumption of certain azo-dyes and their effect on childhood behaviour[1]. In 2007 a study was published by researchers from Southampton University on the effect of a combination of certain artificial food colours and sodium benzoate on childhood behaviour. The study supported a possible link between the consumption of these artificial colours and a sodium benzoate preservative and increased hyperactivity in 3-year-old and 8/9-year-old children in the general population.

These azo-dyes have become known as the 'Southampton 6' colours and they are as follows:

- sunset yellow FCF (E110) – provides an orange shade
- quinoline yellow (E104) – provides a yellow shade
- carmoisine (E122) – provides a red shade
- allura red (E129) – provides a red shade
- tartrazine (E102) – provides an orange shade
- ponceau 4R (E124) – provides a red shade

Following this study the Food Standards Agency (FSA) suggested that parents of children showing signs of hyperactivity might choose to avoid giving the colours used in the study to their children.

UK Ministers and the FSA also encouraged food manufacturers to comply with a voluntary ban on these colours. Subsequent to this a European Union-wide compulsory warning ('may have an adverse effect on activity and attention in children') must now be put on any food and drink product that contains any of these six colours (excluding drinks with over 1.2% alcohol). Any food or drink product, containing one or more of these colours, placed on the market after July 2010 must now carry this warning. More guidance on the labelling requirements for products containing these colours can be found on the Food Standards Agency web site (www.food.gov.uk).

There is consequently a desire by many food manufacturers to remove all of these six colours from food and beverage products and to replace them with alternative colouring. The six colours cover yellow, orange and red shades. Manufacturers developing new food products also want to avoid using these colour additives in their products. Several options are possible for the manufacturer to do this. Colours could simply be removed; this option is likely to be viable for a very small number of products. The products could be reformulated using proportionally more of any highly coloured ingredients already in the product – for example increasing the existing concentration of the fruit or vegetable component. This may again only be feasible for a few products as the cost of increasing the proportions of these ingredients may not be economically viable.

The majority of food manufacturers will need to look at the use of either another colour additive (or blend) or a colouring foodstuff (or blend) in order to replace one or more of the six colours from the Southampton study.

This guide describes the options currently available to manufacturers looking to replace one or more of the colours. It aims to provide food businesses with information regarding colouring options as alternatives to the colours known as the Southampton 6 colours to enable them to converse appropriately with their suppliers to ensure that any replacements they are considering are the best for their business and product.

Unfortunately, often a single food colour cannot be used as a direct replacement for one of these colours. Often manufacturers will need to use a blend of food colours in order to achieve the best match. Sometimes a small amount of food colours of other shades will be required in this blend – therefore this guide gives details of other food colours outside the red/orange/yellow shades.

2: Colour options available to manufacturers

Food manufacturers have two main options when replacing one or more of the six colours: to either use an approved colour additive or a colouring foodstuff.

2.1 Additive colour definition

Colouring additives have an EU definition set out in Regulation 1333/2008 on food additives:

'Colours' are substances which add or restore colour in food, and include natural constituents of foods and natural sources which are normally not consumed as foods as such and not normally used as characteristic ingredients of food. Preparations obtained from foods and other edible natural source materials obtained by physical and/or chemical extraction resulting in a selective extraction of the pigments relative to the nutritive or aromatic constituents are colours[2].

Even though there is no legal distinction between colours that have been chemically synthesised and those that have been derived from naturally occurring materials, many food retailers and food manufacturers prefer to use colours from naturally derived sources. The food industry tends to classify colours in the following way:

- Chemically synthesised colour
    - artificial colours e.g. tartrazine or Green S
    - synthesised colours identical to those pigments in nature – e.g. synthetic beta-carotene or riboflavin
- Colour derived from natural sources
    - Colour selectively extracted by solvents e.g. anthocyanins
    - Colour selectively extracted by solvents then chemically modified e.g. copper chlorophyll[3]

Many retailers and food manufacturers are keen to reduce the amount of artificial additives used in foods. Therefore, many food companies prefer to avoid using colours that have either been chemically synthesised or chemically modified after extraction. No matter which of these colour types is used, all added colours must be declared on the label of a food product. Along with the designation "Colour:", manufacturers can choose to declare these either by name or E number. The colour regulations vary worldwide and therefore if a coloured food product is to be sold outside the EU the regulations for the country of sale must be consulted.

2.2 Colouring foodstuffs definition

The drive to remove artificial additives from food and beverages has led to more interest in using highly coloured foodstuffs to colour food. The EU legislation does not define a colouring foodstuff. Rather, this group is made up of those foods/food ingredients that provide colour to a compound food, but fall outside the definition of a food colour. Food colours require pre-marketing/use approval under the EU legislation; colouring foodstuffs do not.

EU additives legislation defines certain substances that are not considered to be additives (and therefore not food colours) as:

Foods, whether dried or in concentrated form, including flavourings incorporated during the manufacture of compound foods, because of their aromatic, sapid or nutritive properties together with a secondary colouring effect[2]

In addition, referring back to the definition of a food colour, a preparation obtained from foods and other edible natural source materials obtained by physical and/or chemical extraction that does ***not*** result in a selective extraction of the pigments relative to the nutritive or aromatic constituents is ***not*** a food colour within the meaning of the EU Regulation.

For a food used as a colouring not to have been selectively extracted it would be expected that it would retain much of the original characteristics of the raw food such as colour, flavour and taste. If the ingredient to be used for colouring a product is a food ingredient that is commonly consumed in the EU, then it clearly can be considered a food and is not subject to the colour regulations. For example a spinach puree (cooked, milled, dried or concentrated) used to impart a green colour to a food product is clearly a food. Other typical examples are ingredients such as herbs and spices whose main function is to impart a flavour to a food product, but may have a secondary colouring effect. For example saffron would not be considered a colour additive as it imparts flavour to food. However, the situation concerning food raw materials that have in some way been extracted for the primary purpose of colouring is more complicated as these may well fall under the scope of additives legislation. There is a wide range of commercially available colouring foodstuffs, many from fruit and vegetable products, available from ingredient suppliers. These are now widely used in the UK food industry to impart an array of colours to food and beverages.

At the time of publication, there is an ongoing debate within the EU regarding ways of distinguishing colouring foodstuffs (which do not require approval under EU food additives legislation) from food colours (which do require approval). Both Industry and regulators consider there is a difficult legislative boundary between a food colour additive and a colouring food and the European Commission and Member States are working on guidance.

The future legislative status of these products, which are considered to be colouring foods in some parts of the EU, will depend on the outcome of the exercise described above. If a substance/preparation is deemed to fall under additives legislation it will then need to undergo a safety assessment before being approved as an additive. If it is considered to be a food used for colouring purposes, it will fall outside the scope of the colours legislation and, as a food ingredient, will not need to be tested for safety. The choice of whether to use a colouring food, which may result in a more consumer friendly label, needs to be weighed against the risk that the substance in question may eventually be classified as a colour which will require approval or no longer be permitted for use in foods.

The decision of whether to use a colouring foodstuff rather than an additive colour should also be weighed against issues such as flavour carry over, increased usage levels and increased risk of hazes. Blends of some colouring foodstuffs may be required to achieve the desired colour. Examples include blends of fruit concentrates containing anthocyanins and paprika extracts to produce a desired red colour shade[4].

The properties of colouring foodstuffs are mainly determined by the colour pigment they contain. For example a red fruit juice concentrate will contain high levels of anthocyanin pigment and will have similar properties to anthocyanin additive colour.

2.3 Main colouring additive pigments

There are four main classes of plant pigment: chlorophylls, carotenoids, anthocyanins and betalains, which account for the majority of naturally derived colours added to food[5]. An understanding of the properties of each pigment is helpful when reformulating to remove one of more of the Southampton six colours, as colours derived from natural sources are typically less stable than chemically synthesised colour.

2.3.1 Anthocyanins – red/purple/blue colour shades

Anthocyanins are found in a wide range of flowers, fruit and vegetables, being responsible for their red to purple colours. The shade of the red/purple colour exhibited by anthocyanin is dependent on pH, with the colour changing from red through purple to blue as pH increases. As a result, when using anthocyanin colour it is important to know the pH of the food product you are colouring. Anthocyanin colour is more stable below pH 4 when it is red, so is often used in acidic foods. Anthocyanin pigments are water soluble and are able to withstand short periods of moderate heating. Similar to other colour pigments, the colour of anthocyanins will fade over time on exposure to light. The presence of ascorbic acid may also cause the colour to brown or fade over time. In fortified beverages, 250ppm ascorbic acid can cause colour loss of up to 50% within the first three months of storage[6]. Colour fading and browning can cause an issue with product shelf-life depending on the application and form of anthocyanin used.

The scientific literature describes nearly 300 different anthocyanins[7], with different anthocyanins having different chemical structures. This can affect their stability. Anthocyanins have been extracted from blackcurrants, grape skins and elderberries for many years, but more recently new sources such as radish, red cabbage, and black/purple carrot have also been utilised due to their better stability. Anthocyanins from these new sources have an acetylated structure, which has been shown to retain more colour at higher pH values than non-acetylated forms. Acetylated anthocyanins also have more stability to factors such as heat, light and the presence of sulphur dioxide[8]. The use of colours containing acetylated anthocyanins increases the pH range over which a stable red colour is possible[9]. Research is continuing on examining the structure and stability of anthocyanins from a variety of fruits, vegetables and flowers in order to find new and possibly more stable sources of anthocyanin colour. Studies over the last few years have examined purple and red flesh potatoes[10], purple corncobs[11] and sorghum[12]. Food colour manufacturers are active in this area in order to provide food manufacturers with a wider selection of colours with different stabilities. For example, ColorMaker in partnership with D. D. Williamson have developed a natural blue colour from anthocyanins that has a shelf-stable blue hue at pH values between 5.5 and 8 (www.ddwilliamson.com)

Anthocyanins are used to colour a wide range of food products. Typical applications include soft drinks, jellies and yoghurts, but as more stable forms of anthocyanin colours have become available this has provided a widening range of available shades and resulted in the number of food applications they are used in increasing.

2.3.2 Betalain – red/pink colour shades

The main edible source of betalain is beets, but in recent years the betalain in the prickly pear has been explored[13]. The betalains, like anthocyanins, are water soluble pigments. They consist of two structural groups: the red-violet betacyanins and the yellow betaxanthins[14]. Only the betacyanin pigment in red beets (betanin) is approved and is now used extensively as a food colouring as it produces an attractive range of pink/red shades in food and beverages. Beetroot juice has been added to food for its colour since the eighteenth century. Some varieties of beetroot are very rich in this pigment, containing up to 200mg/100g of betacyanins[15].

When used as a colouring, beetroot juice is pasteurised to reduce micro-organisms. It can contain up to 70% sugar and 0.5% betanin pigment. The colour content can be increased through fermenting the juice, removing the alcohol during a concentration step. As with many colours, beetroot juice can also be spray dried on to a carrier to produce a powder. Betanin is a strong colour so quantities required to colour a food or beverage are typically low.

Betanin is quite sensitive to heat and can be prone to oxidation in aqueous beverages with a high water activity (Aw). It is pH stable in the range of most foods (pH 3 to 7) and shows optimum stability at pH 4.5. Therefore, it is more suitable for use in products with a short shelf-life than the anthocyanin based colours. During prolonged heating betanin will turn brown, making it unsuitable for many heat processed food applications. However, it can sometimes be used for pasteurised chilled dessert and beverage products that are only exposed to a short mild heat treatment. As a result, beetroot colour is best added at a late stage in the process to try to avoid excess exposure to heat. At high sugar, and therefore low water activity levels, the betanin pigment is more stable to heat[16]. Betanin can also be susceptible to oxidation resulting in colour loss, which can be counteracted by the inclusion of anti-oxidants into the formulation. A review of the published literature[14] reported that ascorbic acid tends to increase betalain stability. Herbach *et al* (2007)[17] looked at betacyanin stability in purple pitaya (a fruit from a cactus plant) juice during processing and storage. They concluded that the addition of 1% ascorbic acid reduced the damaging effects of light on the colour during storage.

2.3.3 Carmine, cochineal and carminic acid – orange/red/pink colour shades

Cochineal is another colour with a long history of use, originally used for colouring fabrics before being used in food. It can produce deep orange to red shades in food products. The cochineal is extracted from female cochineal insects found on cacti in Peru, Mexico and the Canary Islands. Cochineal is produced by crushing the insect bodies and the colour can account for up to 22% of the insects' dry weight. The main colouring pigment in cochineal is carminic acid, which is water soluble and stable under acidic conditions. Carminic acid can be extracted from cochineal and then precipitated with aluminium, magnesium or calcium to form a lake[18] (an insoluble form of the dye; more information on lakes is given in Section 3.4). This carminic acid lake is termed carmine and usually contains around 50% carminic acid. Carmine can provide a range of different shades from red to purple depending on the metal used to form the lake. Carmine is a more intense red pigment than carminic acid which tends to give a more orange shade[15]. In the EU, cochineal, carminic acid and carmine have the same E number (E-120). This colour group of cochineal, carminic acid and carmine are sometimes referred to as 'carmines'. They are not generally accepted as kosher and products containing this colouring are not suitable for vegetarians.

Carmine is a particularly stable colour and is able to withstand sterilization and baking temperatures. Carmine also binds strongly to protein and therefore works well in meat and fish products, such as surimi, where it binds into the structure. Carmine is not soluble below pH 3 and is likely to precipitate below this. Carminic acid pigments are sensitive to pH and can change from orange shades at very low pH, to red at slightly acidic pH and blue/violet at neutral pH[19]. Cochineal, carmine and carminic acid are widely used in the food industry in products including bakery, confectionery, desserts and processed meat.

2.3.4 Lycopene – yellow/orange/red colour shades

Lycopene is a carotenoid pigment with a structure similar to carotene and is found in small quantities in many fruit and vegetables. Tomatoes are the major source of this pigment. Watermelon and red grapefruit contain only moderate amounts of lycopene[18]. It can produce colour shades from red to yellow depending on the level used and the food application. It tends to be more expensive than other carotenoid pigments[19].

Lycopene based colours became available due to a combination of the development of a tomato cultivar with very high lycopene content and improved production practices[20]. Lycopene from tomatoes was approved as a food colour in Europe in 1997 and in the US in 2005[19]. At the time of writing this guidance only lycopene extracted from tomatoes is approved as a colorant in the EU but two other sources are likely to be permitted from autumn 2011.

Formulations based on dissolved or emulsified lycopene produce a yellow to orange colour while fine dispersions of lycopene crystals are required to give a red colour[21]. In the presence of both heat and fat, the crystals will dissolve and this leads to the colour moving from a red to an orange shade. The rate of colour change depends on fat content, the saturation level of the fat and the temperature of the process[22]. At levels above 8% fat it is difficult to get a red colour. When compared to beta-carotene, less lycopene is required to produce a colouring effect as dispersed lycopene has a colour intensity 6-8 times greater than that of beta carotene[22]. Lycopene colouring is sensitive to oxidation but stability can be improved by the incorporation of ascorbic acid. Depending on the application, lycopene colouring will also give a degree of cloud to a product.

Lycopene colour formulations are much more effective than using tomato paste as a colourant. LycoRed, a carotenoid ingredient supplier, has developed a patented technology that reduces the size of lycopene crystals to 1-3 microns, smaller than those found in tomatoes in nature. These suspended micronized lycopene crystals produce a more intense red colour shade and are sold under the brand name Tomat-O-Red[23].

The colour shade of lycopene is similar to that of ponceau 4R and allura red when these colours are used at low levels. Lycopene appears more orange as the dosage used increases. Lycopene can be used for neutral panned sweets where a heat stable, vegetarian and kosher red colour is required. It is not permitted in meat products but can be used successfully in processed fish, for example surimi (information supplied by Lycored Ltd).

2.3.5 Paprika - orange/red colour shades

Paprika is used extensively in the food industry as it has high pigment content and can be used both as a spice and a food colour. It is produced from pepper varieties (*Capsicum annum*), which are dried and then ground. It contains a number of carotenoid pigments, the main three being beta-carotene, capsanthin and capsorubin, all of which provide an orange-red colour to food. The amount of pigment depends on the maturity of the capsicum plant, plant species, production climate and method of cultivation[24]. The use of paprika to colour food has traditionally been limited to spicy savoury products due to its distinctive flavour and heat. Deflavoured paprika colour is available for sugar confectionery, dairy products and beverages. However, in mild flavoured food products the paprika may still be detected.

A paprika oleoresin (a mixture of oil and resin) can be produced by solvent extraction of the pigments. For food colour applications this is usually made from pepper varieties with little pungency and flavour[19]. Paprika has fairly good stability to heat and pH, but like other carotenoids, is sensitive to oxidation especially when exposed to light[25]. To improve stability to oxidation colour manufacturers have included antioxidants in their formulated paprika based colours. There is increasing interest in exploring the use of natural anti-oxidants such as rosemary or tocopherol extracts for preventing oxidation. Paprika is oil soluble, but colour manufacturers have developed water soluble forms, with encapsulated water soluble forms having higher light and heat stability[26].

2.3.6 Annatto, bixin, norbixin – yellow/orange colour shades

Annatto is a colouring obtained from the seeds of *Bixa orellana*, a bush grown in Central and South America. Annatto has been used as a food colouring for over a century and contains both bixin and norbixin pigments. Bixin is extracted from the seed coating and is oil soluble so suitable for fat and oil based applications such as margarine, and other fat emulsions as well as extruded savoury snacks. The extraction of annatto using alkaline hydrolysis results in a second water soluble pigment, norbixin[19], which is suitable for applications such as fine bakery wares, some breakfast cereals, cheese, desserts and smoked fish. Annatto, bixin and norbixin are only permitted in a limited number of food types and maximum levels permitted are stipulated in the regulations. Annatto is not permitted in sugar confectionery. Annatto colour can contain varying amounts of colouring compounds depending on the extraction and processing temperature used; this will also affect the colour hue obtained in the food.

Norbixin may be spray dried on a carrier such as modified starch or maltodextrin to produce a water soluble powder that can contain up to 15% of the pigment. Norbixin can be sensitive to sulphur dioxide and both low pH and hard water can cause precipitation[27]. The addition of calcium ions can result in precipitation.

Bixin and norbixin have relatively good stability to heat and light when bound to starch or protein, but are much less stable in aqueous solutions. Annatto may precipitate in an acidic medium and water soluble annatto is not stable at very high process temperatures[28]; for example there is around a 50% loss of colour in sugar cones coloured with annatto when processed at 130°C and almost complete loss of colour in wafers when heated at 250°C. When food products containing bixin or norbixin are either heated or stored, the shade of the colour becomes more red and less yellow[29]. The oil soluble bixin pigments, similar to other carotenoids, are sensitive to oxidation. This sensitivity is increased in the presence of light, so anti-oxidants are often used in the formulation to protect the colour.

2.3.7 Carotenes/Beta carotene – yellow/orange/red colour shades

E160a covers both mixed carotenes and beta-carotene. Mixed carotenes are a combination of both alpha-carotene and beta-carotene. Beta-carotene is one of the most common carotenoids and is used widely in the food industry as a food colouring. Carotenes can be extracted from a number of sources including algae, carrot and palm oil, or produced by the fermentation of micro-organisms[30,20,31]. It can be produced from the algae *Dunaliella salina* which is commercially grown under conditions that allow the algae to accumulate up to 10% of their dry weight as beta-carotene. However, historically the majority of beta-carotene used in food production has been a form produced by chemical synthesis that is identical to the form found in nature. Increasingly, food manufacturers are changing to beta-carotene derived from natural sources, which are now offered by several colour suppliers, even though these are significantly more expensive and still limited in supply. Beta-carotene manufactured synthetically or derived from a natural source has the same E-number (160a).

With new formulation technology the range of shades available from carotenes available to food manufacturers has increased and now includes more red shades as well as yellow and orange. A very fine dispersion of beta-carotene will result in a yellow colour and a high colouring strength. As the particle size increases the colour solution becomes redder. Colour formulations with improved handling properties have also been developed. As with all the carotenoids, carotenes are oil soluble with water soluble forms being produced by emulsification. Therefore most beverages using carotenes as colouring will be slightly opaque in appearance. The colour shade produced by a beta-carotene or mixed carotene emulsion will depend on the ingredients in the formulation used, the dispersion method, as well as the concentration and the type of food or drink product in which it is incorporated. Spray dried powders are also available.

Carotenes are susceptible to oxidation, particularly in the presence of light, and as a result anti-oxidants are typically included in colour formulations to protect them. The use of beta-carotene colouring emulsions in orange beverages has sometimes resulted in an unsightly oily ring forming at the neck of the bottle during storage. However, new formulations have now been designed that are less susceptible to ring formation.

2.3.8 Curcumin - yellow colour shades

Curcumin is the bright golden yellow pigment found in turmeric. The use of turmeric to colour and flavour food has been common practice for many centuries particularly in curries. Along with the bright yellow colour it also imparts a characteristic spicy flavour to food. Curcumin is extracted from the dried tuber, or rhizome, of the turmeric plant *Curcuma longa* by grinding the tuber followed by solvent extraction. The solvent extraction helps to remove the spicy notes. *Curcuma longa* has a higher pigment content than the turmeric species used for the commercial production of turmeric as a spice. In aqueous solutions it provides a bright lemon yellow shade. A turmeric oleoresin can be made by solvent extraction and crystallisation which helps to remove the spice flavours and concentrate the curcumin pigment. Curcumin can be produced by chemical synthesis but it is only approved in the EU as a food additive if extracted from turmeric.

Colouring products for use in the food industry have a curcumin content of between 4-10% which is dissolved in vegetable oil. Curcumin is an oil soluble pigment, but can be made water soluble by emulsification technology. Powder formulations are also produced by spraying onto a suitable carrier.

Curcumin is stable to pH in the range of most foods but turns orange and unstable at pHs over 7. It is stable at low pH but its yellow colour exhibits a distinct green tinge. It is not suitable for food and beverages in transparent packaging as it is particularly sensitive to light. It is suitable for products protected from light such as dry mix foods and products packed in metal packaging. It has very good stability to heat, but is sensitive to the presence of sulphur dioxide at levels of 100ppm. Curcumin is used to colour a variety of foods including dairy products, fat emulsions, confectionery, soups and sauces. It is sometimes used in blends with annatto, but (as with all blended colours) it should be checked that both/all colours are permitted in the food product of interest and are added within permitted levels.

2.3.9 Lutein – yellow colour shades

Lutein is a carotenoid pigment, found in high concentrations in green leafy vegetables, alfalfa and the petals of marigold (*Tagetes erecta* L.). Oil soluble lutein colour is usually produced from marigolds or from alfalfa grass as a by-product of chlorophyll extraction[18]. After solvent extraction the extract is concentrated and de-odourised. Lutein is available either suspended in oil or in specially formulated water dispersible forms usually produced by emulsification. It is used to provide a golden yellow colour in a range of food and drink including beverages and desserts.

Lutein's chemical structure is similar to beta-carotene, but it shows improved stability to both heat and oxidation. However, exposure to oxygen particularly in the presence of light will still cause the colour to fade. Fading can be prevented or reduced by the addition of antioxidants into the formulation. It is stable to variations in pH having a constant colour shade at the typical pH range of food and drinks. It is generally not widely used in the food industry as some of the other colourings, possibly due to a higher cost compared to annatto and curcumin. However, lutein does show much higher stability to light when compared to curcumin and in the EU it is permitted in a wider range of foods and beverages than annatto.

2.3.10 Chlorophyll and Copper Chlorophyll – green colour shades

Chlorophylls are green pigments present in all plants and algae that photosynthesise, meaning they are abundantly distributed[32]. The main sources used to produce these natural colourings are alfalfa, spinach, grass or nettles; these are typically dried before solvent extraction[33]. Solvent extraction results in an oil soluble product which is standardised with vegetable oils for use as a food colourant. Colour suppliers also produce chlorophyll colour emulsions that can be mixed with water.

There are several different types of chlorophylls (chlorophyll a,b,c,d or e), with all land plants and some bacteria containing chlorophylls a and b. The other chlorophylls (c, d, and e) have only been found in algae. Each chlorophyll type has a slightly different green colour. Chlorophyll a has blue-green tones whereas chlorophyll b has a greener colour. However, the structure and therefore the stability of all the chlorophylls are very similar.

Chlorophyll has a chemical structure which incorporates a magnesium ion within a porphyrin ring. During the extraction process the pigment is removed from the protection of the plant cells and the magnesium ion within the porphyrin ring can be lost, which results in the bright green pigment turning a duller, olive to grey green colour[31]. This creates a pigment that is sensitive to light, pH and heat. Future research is investigating other potential sources for chlorophyll and genetically mapping raw materials to find those that have higher initial chlorophyll contents.

To improve the stability of chlorophyll based food colour, the magnesium ion in the chlorophyll structure can be replaced with copper. This not only creates a more stable complex, but also gives greater colour intensity. Copper chlorophyll possesses moderate heat and light stability, but it will precipitate in acidic conditions.

Due to the considerable difference in the chemical structure there are two different E-numbers for chlorophyll derived colours. Chlorophyll and chlorophyllin are E140 and copper complexes of chlorophylls and chlorophyllins are E141. As copper chlorophylls and copper chlorophyllins are chemically modified natural extracts, some food companies and retailers may avoid using them in their food products

One particular processing area that has caused manufacturers problems when attempting to replace artificial colours has been in canned peas, particularly processed or mushy peas. These products are usually produced by rehydrating and processing dried peas that have already lost much their chlorophyll content and green colour. Traditionally a combination of artificial colours have been used (tartrazine and green S) in order to produce the bright green colour required by consumers. Some of the major food retailers have now replaced these with a combination of copper chlorophyllin and carotenes (by personal observation).

2.3.11 Caramel – brown colour shades

Caramel is one of the most widely used colours in the food industry, where it is best known for colouring cola products. There are four main caramel classes of this water soluble pigment which are based on the chemical reactants used in their production. Each type of caramel is suitable for different applications.

- Plain or spirit caramel (E150a) – used for high proof alcoholic beverages
- Caustic sulphite caramel (E150b) – used for high proof alcoholic beverages with tannins
- Ammonia or beer caramel (E150c) – used for beer, baking, sauces and gravy
- Sulphite ammonia caramel (sometimes known as soft drink caramel) (E 150d) – used for soft drinks and general food applications

The caramels are made by heating sugars (e.g. glucose syrup, sucrose and dextrose), followed by reacting with sulphites, ammonia or ammonium salts which chemically modifies their structure. It is important to select the right caramel as the incorrect class can result in quality issues in the final product, for example hazes or separation.

E150b, 150c and 150d are avoided by some retailers and manufacturers due to their chemical modification. This has resulted in caramel syrup, sometimes referred to as burnt-sugar syrup, being used instead. This is produced by heating sugar solutions. This would be considered a colouring foodstuff. Burnt sugar syrup has limited stability in acid systems due to a tendency to precipitate, which means it is not suitable for cola beverages. DD Williamson, a supplier of caramel and natural food colourings, has developed an organic caramelised rice syrup that is produced from organic brown rice. It produces a rich brown colour in a range of bakery products.

2.3.12 Iron oxides and hydroxides– red/brown/black colour shades

E172 covers iron oxides and hydroxides that are inorganic and cannot be dissolved in water, organic acid or organic solvent. It is not widely used as a food colour but is stable to light, heat, oxidation and alkali. The shade achieved depends on the particle size but colours are typically dull. It is permitted for use in the EU but not in the US. One example of where iron oxide has been used as a colouring is in cake icing.

2.3.13 Riboflavin and Riboflavin-5'-phosphate – Yellow colour shades

Riboflavin (E101) (vitamin B2) is mainly used to fortify foods but can also provide a yellow green colour to food. It can be produced from natural sources but can also be chemically synthesised to produce a riboflavin identical to the natural form. It is particularly sensitive to light, losing up to 86% of intensity after 24 hours exposure. Therefore where it is used as a food colourant it will need protection, either with antioxidants or suitable packaging. It is relatively stable between pH 2 and 6. It is not widely used as a food colourant probably due to its relatively high cost. One example of riboflavin being used is in cake icing.

2.4 Main colouring foodstuffs

There are now a wide range of commercially available foodstuffs from food colour manufacturers covering a wide range of colour shades including yellow, orange and red. The stability and uses of these are very similar to the corresponding additive colour of the pigment that they contain. So for example a red grape concentrate will contain anthocyanin pigment and will therefore be sensitive to pH in a similar way to anthocyanin colour.

Since colouring foodstuffs have not been selectively extracted, they will contain other components that the corresponding additive colour will not. This may cause some flavour carry over or there may be a haze when used in some products. Often colouring foodstuffs have to be used at a higher level in food and beverages to obtain the same effect as the corresponding colour additive. Colouring foodstuffs also differ from additive colours in that they often require refrigerated storage and have a shorter shelf life. The use of certain colouring foodstuffs should be considered carefully due to the ongoing review over the legal boundary between colouring foodstuffs and food colours. They have been included in this guide as they are currently widely used within the food industry and are likely to be suggested by some food colour suppliers as replacements for some of the Southampton six colours. However, when using them it would be prudent to check whether developments have been made in respect of the particular colouring foodstuff under consideration and if there are any legal issues associated with their use.

Table 1. Examples of commonly used additive foodstuffs and their corresponding major pigment

Colouring Foodstuff	Main colouring pigment(s)	Colour shades
Carrot	Beta-carotene	Yellow/orange
Blackcurrant, black carrot, radish, red cabbage, elderberries, grape	Anthocyanins	Pink/red/purple
Beetroot juice	Betalain	Pink/red
Lemon	Carotenoids	Yellow
Pumpkin	Carotenoids	Orange
Spinach, nettle	Chlorophyll	Green
Egg yolk	Riboflavin	Yellow
Tomato	Lycopene	Red/orange
Turmeric	Curcumin	yellow
Caramelised sugar syrup	Similar properties to caramel	brown

There are several other colouring foodstuffs available from suppliers that contain other colouring pigments, and are from different natural sources to those of the approved colouring additives. Three examples of such colouring foodstuffs that may be suggested in the replacement of the Southampton six colours follow.

2.4.1 Safflower - yellow colour shades

Safflower is a colouring foodstuff obtained from a plant that has been grown from oil seeds for production of oil. The colour comes from the petals of safflower (*Carthamus tinctorius*) and contains both red (carthamin) and yellow pigments. There is a long history of safflower being used to colour foods and it is sometimes referred to as false saffron. The red pigment carthamin is fairly unstable to heat, light, oxygen and pH and fades from red to yellow and is not generally used as a colouring foodstuff. The water soluble yellow pigments used as colouring foodstuffs are generally more stable but only have fair stability to light. Safflower combined with lemon colouring foodstuff has been suggested as a replacement colouring to quinoline yellow.

2.4.2 Sandalwood – red/yellow colour shades

The powdered red wood, which is traditionally used as a spice to colour and flavour foods, is obtained from the Sandalwood or Red Sanders tree *Pterocarpus santalinus*. The principal red pigments in Sandalwood are santalin A and B – polyphenol flavanoids that are not soluble in water. It is normally soluble in alcohol and is available as a liquid or powder, but water dispersible forms are available. At pH above 5 Sandalwood will give a more purple shade. The powdered wood is used to impart a red colour to food, particularly in canned food, spice mixtures and sauces. It has a history in Europe as a red colouring for pickled herrings. It is likely to carry over a sweet spice flavour to a food product.

2.4.3 Barley Malt Extract

Malt can be processed into malt extract which is used in food products as a sweetener. Currently some malt extract is used as a replacement for caramel colours in products such as bakery, meats and pet foods. It has also been used in some cola beverages in the UK. It is stable to light, oxygen, pH and heat but produces a more transparent colour than caramel.

2.5 Summary table of colours properties

Table 2 provides quick reference information on the typical uses and stabilities of the colours outlined in section 2 of this report. The data on the stability of different colouring has been taken from a number of sources including colouring suppliers’ websites. It gives a general guide to typical stabilities. The stability of individual colour ingredients should be confirmed with the colour supplier as some have developed colour formulations with improved stabilities to light, heat, oxygen and pH.

(See Annex A at end of booklet - page 33)

3. How to approach colour replacement in food products

3.1 Defining your product

When either reformulating existing products, or formulating new products, the issue of colour should be considered at an early stage. It is helpful to include the colour requirements as part of the product brief to ensure all aspects of the product are considered when choosing the colouring approach. It is always recommended to work closely with at least one knowledgeable supplier to ensure that technically the best colouring option is selected.

3.2 Colour shade and hue required for product

It is important to decide on the colour, shade and clarity that is required for the product. The greater the flexibility in the shade of the colour the easier it is likely to be to colour the product successfully. It is much easier to colour a new product than to find an exact colour match for an existing product using alternative colourings. The background colour of your product before the addition of added colour is also an important factor when selecting a colour. Colours derived from natural sources are typically less bright than synthetic colours.

3.3 Customer requirements

The customer requirements, either the retailer or the end consumer, must be considered at an early stage. If the customer wants to avoid chemically synthesised colours, only wants to consider colours derived from natural sources or wants to either include or avoid colouring foodstuffs, this must be clarified at the outset. It is also important from a legislative point of view to know which countries the product is likely to be sold in.

Your customer may have religious requirements for the product, for example requiring it to be Kosher or Halal. Alternatively there may be dietary requirements for the product such as being suitable for vegetarians, organic, GM or allergen free. An example of this is carmine; as it is derived from crushing insects is not suitable for inclusion in a vegetarian product and is not considered Kosher.

3.4 Product matrix

The product matrix and formulation will affect how suitable a colouring is for a particular application. You will need to decide whether your product would be best coloured with a liquid or powder form. Knowing what ingredients are going to be in the product is important when selecting the right colouring, an important consideration being whether the product is water or oil based. Water based or oil based foods have different requirements. Colours can be categorised as either dyes or lakes – dyes being water soluble whereas lakes are the insoluble form of the dye. Lakes are used in products with little moisture or with fats and oils, where they are dispersed rather than dissolved in the oil.

The carotenoid pigments, such as lutein, carotenes and paprika, are all naturally oil soluble. However, water dispersible versions are now available from suppliers that will disperse easily without precipitation. These colour emulsions contain both emulsifiers and stabilisers in order to stabilise them. Colour manufacturers have worked on improving water dispersible forms of naturally oil soluble pigments to help overcome issues with this in certain applications, for example to prevent oily rings forming in necks of bottles of orange coloured beverages. Very fine micro-emulsions are also available which improve dispersion and clarity and prevent problems such as colour marbling in the food. For fat based foods naturally water soluble colour pigments such as beetroot can also be formed into stable emulsions which help to ensure even dispersion within the product.

Colour emulsions tend to give the product an opaque appearance so if a very transparent colour is required it may be more difficult to use some colour emulsions, and water soluble colours if available in the required shade may be a better option.

3.5 Product formulation and ingredients

Some ingredients in a food product will improve colour stability whereas others will destabilise a colour. An example of this is metal ions, which have been added to fortify a food or beverage product or are present from a hard water source. These metal ions can destabilise some colours. For example calcium ions can form insoluble complexes with annatto and carmine and cause pigment precipitation[15].

Increasing the total solids or sugar levels in confectionery products for example has a stabilising effect on colours. Beetroot colour is known to be more stable in high sugar confectionery than in more aqueous systems[34]. The level of protein can also have an effect; binding of the colour to the protein makes it more stable. For example the norbixin pigment in annatto binds well to the milk protein in cheese[15].

Another consideration is the presence of alcohol in a formulation as this will affect the stability of some colours. Some types of caramel (plain) will precipitate at a certain alcohol concentration and a more stable caramel type should be selected for this application. The presence of sulphites in a food or beverage can cause colour fading of annatto, anthocyanins and curcumin pigments. Emulsified colour systems may lose stability when incorporated into a food or beverage product containing alcohol.

The physical form of the product will partly dictate whether it is more suitable to use a liquid or powdered colouring. Most colours are now available in both formats. When colouring a multi-component food product, colours that will not move or bleed into other layers are needed, for example in layered desserts. For this application a micro-encapsulated colour, where the pigment is encapsulated into an insoluble carrier such as carbohydrates, gum or protein, can be a good option. Both Sensient and Capcolours by CHR Hanson supply non-migrating colours for this type of application. Microencapsulation can also provide better protection from oxidation or acidic conditions by protecting the colour molecule from oxygen or acid.

In aerated foods such as a mousse or an ice cream, the incorporated air will dilute the colour and a higher level may be required to give the desired colour hue. When replacing a water soluble artificial colour with a water dispersible emulsion of an oil-soluble colour in a food product containing a foam or emulsion structure, the colour emulsion may affect the stability of the food by changing the surface active properties of the food matrix.

When using colouring foodstuffs in mildly flavoured products, flavour carry over from the colouring foodstuff can be an issue. An example of this is where spinach or paprika is used to colour cake icing which can result in the associated flavours being tasted in the cake. This can be a particular problem when a colouring foodstuff is used at a high level to provide a deep colour shade. A possible solution to this is to incorporate a flavouring into the formulation to mask any flavour carry over from the colouring foodstuff.

3.6 Acidity and pH

For some colours, the acidity (and therefore the pH) of the product will have a significant effect on both the stability and the shade produced. The stability to pH for each colour pigment can be found in table 2. The colours that show the most pronounced colour variation with pH are anthocyanins. They change from a red/pink colour at low pH to a more purple/blue colour as the pH increases towards neutral. The stability of anthocyanins also decreases with increasing pH, which limits their use to produce a blue colour. Curcumin is relatively stable to pH, but its yellow colour does develop a distinct green tint at low pH and carmine will precipitate at low pH[31]. It is important to get an even distribution of the acidic ingredients throughout a food product to avoid any colour variation through the product.

3.7 Manufacturing process

The production method and type of processing that the product will undergo will affect the colour. The higher the temperature and the longer the time of processing, the greater the effect on the colour and the more restricted the choice of colours becomes. For example some beetroot red colours should survive a high temperature short time (HTST) pasteurisation treatment for a short shelf life chilled product, but would be degraded by a prolonged in-pack pasteurisation or sterilisation. An indication of the stability of different colours and pigments to heat can be found in table 2. However, advice on the heat stability of specific colour ingredients should be confirmed with the colour supplier.

Sometimes it may be possible to adapt the manufacturing process to improve the colour stability, for example by adding colouring later on in the manufacturing process and thereby minimising the exposure to heat. In this case any microbiological issues arising from this change should be assessed. Products may need to be cooled more quickly to reduce heat degradation of added colours. Sometimes combining colours with other ingredients in premixes can help to improve stability of sensitive colours.

The mixing and filling of the product can also affect the stability of colours that are prone to changes due to increased levels of oxygen. Oxygen can either be entrapped in the product and/ or in the pack headspace. Controlling the amount of aeration during manufacture and vacuum filling and sealing the product may in some cases help to remove oxygen and reduce oxidation effects on the colour. Sometimes nitrogen flushing can be used.

3.8 Desired shelf life

Knowing the desired shelf life is crucial when selecting a colouring for a new food product. Typically colours derived from natural sources tend to be less stable over time than their artificial counterparts as they have a tendency to fade. This could be a problem for products with a very long ambient shelf life. The higher the storage temperature the more fading is likely to be encountered, therefore the ambient temperature for the countries in which the food product will be marketed should be considered. Selection of the correct packaging can in some cases assist with achieving the desired colour throughout the shelf life of your product.

3.9 Packaging

When the selected food colouring is sensitive to oxygen and light the packaging format for the product is important. Many colour pigments will fade or turn brown over time when exposed to light and details of the stability of individual pigments to light are in table 2. Some of the carotenoid pigments, for example curcumin and carotenes, are very sensitive to light. Light promotes the oxidation of natural pigments, but less light sensitive formulations of some natural pigments have now been developed[35]. Food and drink products will generally have only limited exposure to sunlight but could potentially have a much greater exposure to supermarket lighting. The exposure to light of products for foodservice and retail may be different. Light in retail displays can be particularly damaging but this depends on the light spectrum and intensity as well as the length of exposure[36]. Typical light exposure throughout the supply chain should be considered.

The stability of different colour pigments to oxidation also varies. Carotenes and lutein pigments are particularly susceptible to oxidation, which causes the colour to fade. The stability can be improved by physical methods such as encapsulation of the colouring, which effectively shields the colouring pigment from the oxygen. Most colour manufacturers will either include or recommend that antioxidants are added to the colour formulation or to the product when oxygen sensitive pigments are used. This offers some protection against degradation by oxygen. Antioxidants from naturally derived sources such as ascorbic acid, tocopherol and rosemary extract are usually preferred by many manufacturers[14]. These approaches, in combination with the packaging options outlined below, can greatly enhance stability to oxidation.

Where a product has a long shelf life of many months the effect of degradation or fading of the colour due to light and/or oxidation should be considered. In some instances selection of packaging can help to minimise light and oxidation effects. Metal packaging such as a food or beverage can or an aluminium pouch provide very good barriers to both light and oxygen. However for marketing reasons, these are only an option for some food and beverage products. Glass bottles and jars provide an excellent barrier to oxygen but non-tinted glass will not protect from the effects of light. Plastics such as polypropylene have low barrier properties to light and oxygen. The barrier properties can be increased by including a barrier layer in the plastic, for example ethylene vinyl alcohol. UV protection can also be added to some plastics to provide extra protection from light. The extra cost of packaging with the inclusion of barrier layers will need to be considered.

3.10 Selecting your colour and colour supplier

It is recommended that full details of the product to be coloured including likely ingredients, packaging, processing and shelf life should be compiled, before contacting colour suppliers to source the most appropriate colouring for your application. A list of suppliers that have been referred to in this guide or in the writing of this guide are included in section 5. Most colour suppliers offer a range of different colours, but are unlikely to offer every colour available so it is important to contact several suppliers to ensure that the most promising colours are obtained.

It is recommended to speak with a technical contact at the colour supplier and to provide them with as much information on your product as you are able to divulge to ensure you get the most appropriate colour for you product. Having a basic understanding of the properties of the different colourings that are available (as described in section 1) will be very helpful in discussions with suppliers. Many suppliers offer blends of colours or are able to suggest combining two colours together in order to achieve the desired shades. Sometimes combining two colours can lead to instability issues, which a good technical supplier will be aware of.

Colour suppliers have developed colour formulations that either contain added ingredients and/or have specialised production processes designed to improve the stability of the colouring once incorporated into food and beverage products. This includes for example the addition of antioxidants, emulsifiers and stabilisers and the use of encapsulation and micro-encapsulation technology and they should be able to advise you in this area, if necessary.

3.11 Considering legal issues

Food colour regulations are different in other parts of the world. Therefore the relevant legislation on colours should be consulted for each world market in which the food or drink product will be sold. Unfortunately for some applications it may be necessary to use a different colouring or a blend of colours in products sold in different world markets.

In the EU and the UK all colour additives, either natural or artificial, need to be approved for use in foods and beverages. EU regulations relating to colour are referred to in section 1. The EU has commenced a review of all existing approved food additives and has started with food colours. Some opinions already published by the European Food Safety Authority (EFSA) have led to restrictions on use of some existing additives such as limiting the maximum permitted use levels or the range of food and drink categories in which the additive can be used. EFSA opinions on the remaining food colours will be published by the end of 2015.

In the US, FDA Title 21 of the Code of Federal Regulations lists both certifiable colour additives (part 74), and colour additives exempt from certification (part 73). Certifiable colours are those which are man-made, or synthetic. Currently there are 9 certified colours, with 7 approved for general use in foods[23]. The 7 approved colours for general use include some of the Southampton six colours for example FD&C Red 40 in the EU is Allura red (E129) and FD&C Yellow 5 is Tartrazine (E102) . Pigments derived from natural sources are exempt from certification. However the FDA does not consider any colour to be natural where it is being used to colour a product that it is not derived from[23]. Colours that are not certified can be labelled by their name such as 'annatto extract colour'[26]. There are significant differences between the colours permitted, levels, labelling and applications in the US and EU which must be checked carefully if developing a product for export.

When using colouring foodstuffs, manufacturers must ensure that the pigment has not been selectively extracted by discussing the extraction process with suppliers since, within the EU, selective extraction would result in the resultant colour being classed as an additive and would need to have the relevant approval.

3.12 Cost

Colourings are typically used at low levels and costs have generally not been a barrier to the selection of a colouring material. Synthetic colours tend to be of lower cost than naturally derived colours and colouring foodstuffs tend to be the most expensive colouring materials. When using colouring foodstuffs to impart colour to a product, if a deep hue is required then the cost could be a significant factor, as an increased concentration will be required. Cost is more likely to be a limiting factor for inexpensive food products. As with any food product development costings for all ingredients including the colouring component should be calculated as soon as possible to ensure that the proposed product formulation is economically viable. The cost of some naturally derived colourings may vary depending on the supply conditions.

3.13 Security of supply

The market for alternative food colours for the replacement of azo dyes is predicted to increase around the world. For example in the USA the demand for naturally derived colours is expected to more than double, which may place strain on the supply chain. From 2005 to 2009 the world market for naturally derived colours increased by approximately 35% in value[37,26,38] . As most of the colours being used as replacements for the Southampton 6 colours are derived from natural sources rather than chemically synthesised, supply issues caused by factors such as a poor harvest, flooding, drought or war may also have a potential effect on supply. An example of this is carmine, which became in short supply during the summer of 2010. This was thought to be due to weather conditions hampering cochineal production coupled with an increased demand from manufacturers. Coupled with an increase in raw material cost, this led to a large increase in price for this colouring and in suppliers being cautious about supplying carmine to new customers (www.confectionerynews.com – reported Aug 2010). It is important to investigate the issue of supply with colour suppliers to ensure that they will be able to meet your needs. In response to increased use of naturally derived colours and colouring foodstuffs, colouring suppliers are working to develop new cultivars (plants or group of plants selected for desirable characteristics that can be maintained by propagation) to increase the percentage of extractable colour pigment. This alongside improved agronomy will go some way to meet both supply and cost constraints.

3.14 Undertaking initial development trials

Once all suitable colour samples and associated supplier information has arrived, initial development trials can commence. Suppliers should be able to give an indication of the suggested dosage in your particular application. The more information on your product that has been provided, the more accurate their advice is likely to be. However, the colour level will need to be fine tuned in your product. The supplier should also be asked for advice regarding the optimum stage at which to add the colour to the product in order to try to prevent any instability issues.

Typically, initial trials are undertaken on a small bench scale as an initial screening of the sample colour supplied. In this way the colours giving the best match to an existing product can be identified. As with all product development work it is important to keep records of the trials undertaken with a summary of the results. Where possible it is recommended to start storing trial samples at an early stage as this may provide an early indication of any shelf life issues.

It is important to continue to work in partnership with your supplier and discuss any changes that are made to the product during the development process such as a change to the product matrix or the inclusion of an ingredient that may destabilise the colour.

Once successful small scale trials have been completed the development work must be scaled up. Unfortunately what works on a small scale may not transfer smoothly to a larger scale and modifications to the production process for example may be required.

3.15 Overcoming colour development problems

As with all development work there are sometimes unforeseen problems to overcome. If problems are encountered with the colouring the issue should be discussed with the supplier who, with their experience, may be able to suggest a solution, such as an alternative colour or a change to the manufacturing process.

It may be necessary to review the product brief and examine whether compromising on the brief may overcome the issue. Areas to look at include:

- Shelf life required – can this be reduced?
- Can a more stable colour be used – for example could naturally derived colours rather than colouring foodstuffs be used?
- Can the packaging be changed – to give the product more protection from light and or oxygen?
- Can oxygen be removed – for example vacuum packing or nitrogen flushing, or an antioxidant included in the formulation?
- Would a slightly different colour or shade be acceptable?

Any cost associated with changes to the product brief must be examined.

3.16 Shelf life trials

It is essential to undertake thorough shelf life trials to ensure that the new or reformulated product retains an acceptable colour throughout its life. The shelf life testing should be carried out on product samples manufactured under the typical conditions and packed in the final packaging. Sufficient samples should be prepared to allow for testing at regular intervals during the shelf life. Products should be stored under optimum and worst case conditions. For example an ambient stable product for the UK market could be stored at 20°C (optimum) and 25-30°C (worst case conditions).

Where possible a freshly made or in some cases frozen and thawed control sample should be used as a comparison. A panel of at least 2-3 people with good colour perception should be used for the assessment of the samples. Instrumental methods of measuring colours such as a colorimeter can also be useful. Records of shelf life assessment should be maintained.

4. Specific examples of colour replacement approaches to the replacement of the Southampton six colours in different food sectors

4.1 Sugar confectionery

Generally confectionery products are ambient stable with relatively long shelf lives ranging from 6-9 moths for jellies and chews up to a maximum of 18 months for panned confectionery. This long shelf life can be challenging when replacing some of the artificial colours. The artificial colours tend to have intense colour, which is very difficult to match using naturally derived colours. However there is a growing consumer expectation and acceptance that 'non-artificial' colours will not be as bright as their 'artificial' counterparts. In comparison to confectionery on the market 10 years ago product colours are typically more muted and less intense. Many colour suppliers will give advice on what colours or combination of colours from their supplied range can be used to replace the Southampton six colours in confectionery applications. For colouring of sugar coated sweets the colouring used should be stable in a sugar solution with a pH value of between 5 and 6. If the sweets will be exposed to light the colouring should have good light stability. If the colour is heat sensitive such as beetroot it may be necessary to cool the sugar solution slightly before the colouring is added. The colour and flavouring supplier Wild gives several examples of confectionery formulations coloured using colouring foodstuffs on their website (www.wildflavors.com).

Some examples of alternative colours for the Southampton 6 colours from 3 different suppliers are given in Table 3.

Table 3: Replacement of Southampton six colours in confectionery products

Synthetic colour	E-number	DD Williamson replacement	Overseal Natural Ingredients replacement	Wild replacement
Allura Red	E129	Elderberry Beetroot red	Carmine Beetroot red Anthocyanin in combination with carotene	Beetroot red, Anthocyanins, Carmine/Cochineal
Ponceau 4R	E124	Black carrot Elderberry, Beetroot red	Carmine Beetroot red Anthocyanin in combination with carotene	None stated
Tartrazine	E102	Turmeric/Curcumin Lutein Carotene	Safflower with Copper chlorophyllin Lutein Curcumin	Turmeric/Curcumin Beta-carotene
Sunset Yellow	E110	Paprika Cochineal	Paprika	Beta-carotene Paprika
Quinoline Yellow	E104	Curcumin, Lutein, carotene	Safflower with Copper chlorophyllin Lutein Curcumin	None stated
Carmoisine	E122	Grape skin	Carmine Beetroot red Anthocyanin in combination with carotene	None stated

The process of replacing colours is quite complicated and will depend on the formulation and processing conditions used, and while these are confidential to the individual food manufacturer, some manufacturers have chosen to present examples of successful colour replacement in presentations to the food industry at various events.

In a presentation given by Nestlé at Innovations in Natural Colour 2010 conference[39] the evolution of the colour of Smarties was outlined. Prior to 2006 Smarties in Europe contained 4 of the Southampton 6 colours – quinoline yellow, sunset yellow, carmoisine and ponceau 4R with other colours. Between 2006 to the start of 2009 these were replaced with a combination of colours including beta-carotene, copper chlorophyll, riboflavin, and curcumin. Carmine and titanium dioxide continued to be used. In 2009 to 2010 Nestlé replaced the colours in the Smarties in Europe with colouring foodstuffs – replacing the pink, red, purple, yellow and orange colours using lemon, radish, safflower, black carrot, hibiscus and red cabbage.

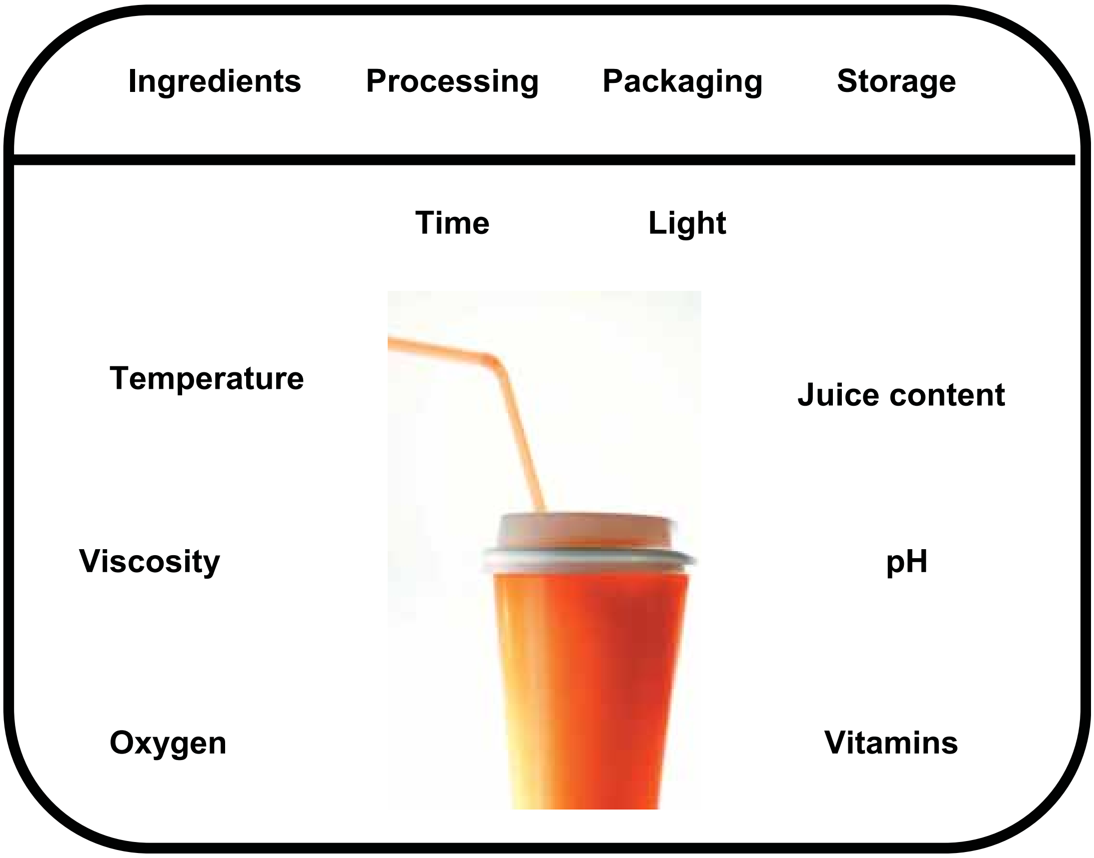
In Nestlé's experience the higher volumes of dry material when using some colouring foodstuffs caused uneven mixing in the product. The requirement of controlled temperature storage and transportation for colouring foodstuffs (unlike most additive colours) increased overall costs. The fact that colouring foodstuffs have a shorter shelf life before use also provided some logistical problems that had to be overcome.

In a presentation at the Biscuit, Cake, Chocolate and Confectionery 2009 Annual conference the British Retail Consortium outlined a case study on the replacement of allura red in Turkish delight. As Turkish delight is heated to a high temperature during the production process it was not possible to use a beetroot colour as an alternative. The company involved worked closely with suppliers and after 20 trials produced an acceptable red colour in the product using a combination of red fruit and vegetable concentrates[40].

4.2 Beverages

The replacement of the Southampton six colours in beverages has already been undertaken by several manufacturers. It is difficult to provide general advice on their replacement as beverages vary greatly in terms of their matrix, ingredients and pH, as well as their exposure to heat, light and oxygen. For example, to replace sunset yellow in pasteurised beverage, you could use a turmeric or curcumin based colour in a canned drink. However, if the product was packed in a clear bottle, turmeric would not be suitable due to its poor light stability.

Figure 1 summarises the many factors that can affect the colour of a beverage product and must be considered when selecting suitable colours.



(adapted from Stich and Court, 2006[38])
Figure 1 – Factors affecting the colour stability of a beverage

Anthocyanin colours work well in some low pH red beverage applications but are not suitable for applications at neutral pH. For beverages with a low pH anthocyanins derived from grapes can give a clear violet-red colour. For very bright red colours elderberry concentrates are preferred[41]. For applications such as a strawberry milkshake it may be possible to use a beetroot red colour which is stable at neutral pH. Beetroot red however only has limited stability to heat so if a UHT process is required a lycopene or carmine colour may work better.

Many of the carotenoid colourings such as beta-carotene and paprika are suitable for replacing the yellow and orange Southampton six colours, with beta-carotene generally being used for yellow and light orange colours and paprika for deeper orange shades. However as these are not water soluble it makes them more difficult to disperse and use in beverages. Colour suppliers do supply emulsions of these colours that are suitable for beverages. For example Overseal Natural Ingredients supplies a soluble range of these pigments (Em-Seal range), which have good dispersibility. If a completely clear orange drink is required Overseal offers Clear-col micro-emulsions which have oil droplet sizes of around 0.1µm. CHR –Hansen also offers natural colours in its Cap Colours range which have improved stability to light and oxidation and include water dispersible forms of the oil soluble pigments.

There are many beverage products on the UK market that have been reformulated over the last few years to remove the Southampton six colours. Many of the supermarket retailers have been particularly proactive in removing not only the Southampton six colours but all other synthetic colours from their soft drinks. Some examples of such replacements are given in Table 4.

Table 4: Examples of the replacement of some of the Southampton six colours in commercial beverages

Product	Original colour	Replacement colour
Asda Cherryade	Carmoisine	Anthocyanins
Yazoo Strawberry milk drink	Ponceau 4R	Beta-carotene
Crusha Raspberry milkshake syrup	Carmoisine	Carmine
Tizer	Ponceau 4R and sunset yellow	Carrot and Safflower

As the formulation, processing and packaging of beverages varies widely many colour suppliers are wary of giving generic advice regarding specific colours for replacing the Southampton six colours, instead preferring for manufacturers to speak to them directly regarding their particular applications. The supplier D.D. Williamson has provided some information on typical colours used for replacement in beverages, as shown in Table 5.

Table 5 – Alternatives to the Southampton six colours in beverages

Synthetic colour	E-number	DD Williamson replacement
Allura Red	E129	Cochineal, Elderberry, Purple carrot
Ponceau 4R	E124	Purple carrot
Tartrazine	E102	Curcumin, Lutein Carotene
Sunset Yellow	E110	Paprika Cochineal
Quinoline Yellow	E104	Curcumin Natural carotene
Carmoisine	E122	Grape skin Cochineal

(source: www.dddwmson.com)

Many suppliers will provide recommendations for natural colours for beverages for typical products. For example Overseal Natural Ingredients provide tables for both carbonates and ready-to-drink beverages as well as cordials and squashes, listing recommendations for the different colour/flavour shades required.

4.3 Replacement of colours in meat and fish applications

Many meat and fish products do not contain added colours but there are a few products where the addition of colour, including some of the Southampton six colours, is common. One area is in curries primarily from Indian takeaways. The vast majority of supermarket curry and curry sauces no longer include any of the Southampton six colours in their formulations. Instead the orange, red and yellow colours are produced using a combination of naturally derived colours and ingredients; for example tomato puree, turmeric spice and colour as well paprika colour, which is included in a large number of products.

One problem area appears to be the colouring of tandoori paste, used to produce such products as tandoori chicken. The UK consumer has got used to the very intense bright red colour that is normally produced from the inclusion of either allura red, carmoisine or ponceau 4R, which are also sometimes combined with sunset yellow. There are some restaurants and takeaways no longer including these colourings in their tandoori recipes however, they may have to explain to their customers the reasons for the differences in colour. The Tiger Tiger brand of Tandoori paste is formulated with anthocyanin and paprika but this produces a slightly more orange brown colour than the bright red often associated with tandoori recipes. Asda uses a combination of beetroot red and paprika extract colours to give its chilled chicken tandoori masala products a red orange colour. Carmine is also declared as an ingredient in the tandoori paste used to produce its tandoori sizzler paste.

Smoked haddock used to be coloured with either tartrazine or quinoline yellow, but these are now more commonly coloured with naturally derived colourings; for example, Asda and Young's use a combination of annatto and curcumin, while Sainsbury's declares curcumin and paprika in its skinless and boneless haddock fillets. Uncoloured smoked haddock fillets are also available.

5. Further sources of information

5.1 List of colour suppliers

Company	Web link	Description
ACTIV International	http://www.activ.fr	Provides natural colouring agents for food applications but particularly for processed fish and seafood applications
Allied Biotech Europe	http://www.altratene.com	Full range of carotenoid colours
CHR- Hansen UK	http://www.chrhansen.com/products/product_areas/natural_colors.html	Provides a range of natural colours from yellow and orange through pink, red and purple to green, brown and black.
Colin Ingredients	http://www.colin-ingredients.com	Provides an extensive range of colours, suitable for most areas in the food industry.
Colorcon	http://www.colorcon.com	Provides a range of lake blends, natural colours and oxides.
Cyber Colors	http://www.cybercolors.ie	Specialises in food colours (annatto, anthocyanins, beetroot red, carmine/cochineal, carotenes, chlorophyll, elderberry, and lutein)
Diana Naturels	http://www.diana-naturals.com	Provides highly coloured fruit and vegetable juices and concentrates
DSM Nutritional Products	http://www.dsm.com/en_US/html/dnp/home_dnp.htm	Supplies an extensive range of carotenoids for the food industries. Its products include beta - carotene and lutein.
DD Williamson UK	http://www.ddwilliamson.com	Provides a wide range of natural colourings and an extensive range of caramel and burnt sugar colours. Includes both natural colour and colouring foodstuffs.
GNT Group	http://www.gnt-group.com/en/gnt.php	Provides an extensive range of colouring foodstuffs, suitable for a range of different areas in the food industry.
Lycored	http://www.lycored.com/web/content	Provides a range of carotenoid colourings, with a particular emphasis on lycopene.
Kalsec	http://www.kalsec.com	Provides natural yellow, orange, red orange and pink red colourants suitable for products ranging from baked goods to seafood products.
Kanegrade	http://www.kanegrade.com	Provides an extensive range of natural colorants, in a range of forms (oil soluble, water soluble, powder and liquid).
Overseal Natural Ingredients (Naturex)	http://www.overseal.com/	Overseal produces a good range of colours suitable for a wide variety of different applications such as beverage, confectionery, dairy, margarines and spreads and ready meals. Includes both additive colour and colouring foodstuffs.

Phytone	http://www.phytone.co.uk	Phytone manufactures a wide range of natural colours, including, anthocyanins, Beetroot red, carmine, annatto, carotenes, paprika, curcumin, lutein and chlorophylls, as well as colouring foodstuffs.
Roha	http://www.rohadyechem.com	Manufacturer of both synthetic food colours and natural colouring to the food industry as well.
Sensient	http://www.sensient-tech.com	Provides a range of synthetic and natural colours suitable for all areas of the food industry.
Wild Flavours	http://www.wildflavors.com	Provides a full spectrum of natural colourings suitable for a variety of areas in the food sector both additive colour and colouring foodstuffs.

5.2 Other sources of information

Food Standards Agency website – www.food.gov.uk

Campden BRI – www.campden.co.uk

Natural Food Colours Association (Natcol) – www.natcol.org

6 References

1. McCann, D., Barrett, A., Cooper, A., Crumpler, D., Dalen, L., Grimshaw, K, Kitchin, E., Lok, K., Porteous, L., Prince, E., Sonuga-Barke, E., Warner, J., and Stevenson, J., 2007, Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: a randomised, double-blinded, placebo-controlled trial, The Lancet, 370 [9598] 1560-1567,

2. The European Parliament, 2008, Regulation (EC) No 1333/2008 of the European Parliament and of The Council of 16 December 2008 on food additives, Official Journal of the European Union, No 1333/2008 [L354] 16-33,

3. Salskov-Iversen A, 2009, Industry requirements and trends in food colour., Presentation given at the *Innovations in Food Colour Europe 31st March 2009*, Kingsway Hall Hotel, London WC2B UK

4. McMurray, I., 2008, Colour me beautiful, International Food Ingredients, 6 23-27,

5. Klink, L., 20-4-2004, In living colour, World of Food Ingredients, April-May, [44] 40-42,

6. Klingenberg, A. and Martin, P., 2004, Nature's kaleidoscope of colour, Functional Foods & Nutraceuticals, March, 40-41,

7. Artes, F.,2002, Analysing changes in fruit pigments, 248-282, In: MacDougall D, Colour in fruit; improving quality., Woodhouse Publishing Limited.

8. Christiansen, C., 2005, Natural red coloring, Fruit Processing, 15, [3] 136-138,

9. Bridle, P., 1997, Anthocyanins as natural food colours - selected aspects, Food Chemistry, 58, [1, 2] 103-109,

10. Reyes, L. F. and, L. Cisneros-Zevallos, 2007, Degradation kinetics and colour of anthocyanins in aqueous extracts of purple- and red-flesh potatoes (Solanum tuberosum L.), Food Chemistry, 100, [3] 885-894,

11. Jing, P., Noriega, V., Schwartz, S. J., and Giusti, M., 2007, Effects of growing conditions on purple corncob (Zea mays L.) anthocyanins, Journal of Agricultural and Food Chemistry, 55 [21] 8625-8629,

12. Awika, J. M., Rooney, L., W., and Waniska, R. D., 2004, Anthocyanins from black sorghum and their antioxidant properties, Food Chemistry, 90 [1-2] 293-301,

13. Castellar, M. R., Obón, J. M., and Fernández-López, J. A., 2006, The isolation and properties of a concentrated red-purple betacyanin food colourant from Opuntia stricta fruits, Journal of the Science of Food and Agriculture, 86 [1] 122-128,

14. Herbach, K. M., Stintzing, F. C., and Reinhold C., 2006, Betalain stability and degradation - structural and chromatic Aspects, Journal of Food Science, 71 [4] R41-R50,

15. Henry B S, 1992, Natural Food Colors, 39-78, In: Hendry, G. A. F. and Houghton J.D, Natural Food Colourants, Blackie Publishing.

16. Malien-Aubert, C., Dangles, O., and Amiot, M. J., 2001, Colour stability of commercial anthocyanin-based extracts in relation to the phenolic composition. Protective effects by intra- and intermolecular copigmentation, Journal of Agricultural & Food Chemistry, 49, [1] 170-176,

17. Herbach, K. M., Maier, C., Stintzing, F., and Reinhold C., 2007, Effects of processing and storage on juice colour and betacyanin stability of purple pitaya juice, European Food Research and Technology, 224 [5] 649-658,

18. Francis, F. J., 2002, Food colourings., 297-331, In: MacDougall D, Colour in Food: improving quality., Woodhead Publishing Limited.

19. Mortensen, A., 2006, Carotenoids and other pigments as natural colourants, Pure and Applied Chemistry, 78 [8] 1477-1491,

20. Francis, F. J., 2000, Carotenoids as food colorants, Cereal Foods World, 45, [5] 198-203,

21. Danzig L., 2004, Colour me Tomato, International Food Ingredients, [1] 42-43,

22. Kendrick A., 2009, Lycopene- Formulations to take the pigment from the tomato to table., Presentation given at the *Innovations in Food Colour Europe 31st March 2009*, Kigsway Hall Hotel, London WC2B UK

23. Nachay, K., 2009, A new color palette emerges, Food Technology, 63, [4] 50-52,

24. Ladron de Guevara, R. G. and Dep.de Ciencia & Tec.Agroforestal, Escuela Tec. Superior de Ingenieros Agron. Univ. de Castilla-La Mancha, 2002, Effect of adding natural antioxidants on colour stability of paprika, Journal of the Science of Food & Agriculture, 82, [9] 1061-1069,

25. Henry B. S., 2008, The use of natural colours in food and beverages., Presentation at “Moving away from artificial food colours” A technical symposium organised by the Food Standards Agency in conjunction with the Food and Drink Federation, Wednesday 27th February 2008 held at the Food Standards Agency, Aviation House, 125 Kingsway, London

26. Stout, G. M. and Chr.Hansen Inc., 2002, Exploring colorants from natural sources, Cereal Foods World, 47, [7] 314-316,

27. Phytone, 2011,http://www.phytone.co.uk ,5-2009.

28. Prabhakara R, Akula S, Karakala B, Tummala J, Allani N, and Govardhana R, , 2007, Application of annatto dye formulation in bakery and extruded food products, Journal of Foodservice, 18, [2] 53-58,

29. Prabhakara Rao, P. G., 2005, Effect of processing conditions on the stability of annatto (Bixa orellana L.) dye incorporated into some foods, LWT - Food Science & Technology, 38, [7] 779-784,

30. www.wildflavors.com ,2011,

31. Roenfeldt Nielson, S. and Holst, S.,2002, Developments in natural colourings., 331-350, In: MacDougall D, Colour in Food; Improving Quality, Woodhead Publishing Limited.

32. Hendry, G. A. F.,1996, Chlorophylls and chlorophyll derivatives., 132-155, In: Hendry, G. A. F. and Houghton J.D, Natural Food Colourants, 2nd, Blackie Publishing.

33. Marquez U. and Sinnecker P, 2007, Chlorophylls in Foods: Sources and Stability, 193-213, In: Socaciu C, Food colourants: Chemical and Functional Properties., CRC Press.

34. Delgado-Vargas, F., 2000, Natural pigments: carotenoids, anthocyanins, and betalains - characteristics, biosynthesis, processing, and stability, Critical Reviews in Food Science & Nutrition, 40, [3] 173-289,

35. Searby, L., 2005, Nature's eye candy, International Food Ingredients, [6] 32-33,

36. Manzocco, L., Kravina G., Calligaris S., and Nicoli M. C., 2008, Shelf life modelling of photosensitive food: the case of colored beverages, Journal of Agricultural and Food Chemistry, 56 [13] 5158-5164,

37. O'Donnell, C., 2011, Trends in global coloring, http://www.preparedfoods.com/Articles/Feature_Article/BNP_GUID_9-5-2006_A_10000000000000989569 ,10-3-2011.

38. Stich, E. Court and GNT-Europa, GmbH, 2006, Colouring without colour, Fruit Processing, 3, 161-165,.

39. Tolliday, 2010, The growth of natural colours in Nestlé confectionery, presented at Innovation in Natural Colour 2010 Conference, London 25th February 2010.

40. Martinez-Inchausti, A., 2009, Clean Labels, A Retail Perspective, presented at BCCC Technology Conference 26-27th March in Stratford upon-Avon.

41. Lampe, T. 2003, Colours to bring life to beverage products, Food Ingredients & Analysis International, 24, [2] 18,20-21,

Annex A

Table 2 – Summary of additive colours and colouring foodstuffs that could be used to replace one or more of the Southampton six colours

Colour	Colour pigment	Shade	Typical Applications	Stability of colour			
				Heat	Light	Oxygen	Acid
Anthocyanins E163	Anthocyanin	Red Purple Blue	Soft drinks, jams, sugar confectionery. Yogurt and fruit toppings	Stable	Some stability	Some stability, will slowly oxidise in H20	pH dependent shades. Most stable at <3.8.
Red cabbage, purple carrot, Red fruit concentrates	Anthocyanin	Red Purple Blue	Soft drinks, jams, sugar confectionery. Yogurt and fruit toppings	Stable	Some stability	Some stability, will slowly oxidise in H20	pH dependent shades. Most stable at <3.8.
Beetroot Red E162 And Beetroot colouring foodstuffs	Betalain	Pink Red	Dairy products, ice cream, fruit preparations. Yoghurt, dry mixes, sugar confectionery, low Aw foods that are not highly heat treated.	Sensitive	Fairly stable	Sensitive most rapid in high Water Activity products	Stable between 3 and 7
Carmine E120	Carminic acid	Red	Bakery (as heat stable), confectionery & icing, long life gelatine desserts, meat products as stable in the presence of SO2, long life flavoured milk.	Excellent stability	Excellent stability	Good stability	Fair- below 3.8 it may precipitate
Cochineal E120	Carminic acid	Red	Ice cream, flour & sugar confectionery, dairy desserts, sauces and meat products	Good stability	Good stability	Good stability	Good stability

Sandalwood Colouring Foodstuff	Santalin	Red	Canned food, spice mixes and sauces, pickled herrings	Stable	Stable	Stable	Turns more purple at over pH 5
Annatto E160b	Bixin and Norbixin	Orange	Cheese red Leicester and Cheshire (Norbixin), Vanilla ice cream (with curcumin), sponge cakes, breadcrumbs, wafers, snacks and snacks. Smoked fish	Stable	Stable	Sensitive	Stable
Paprika Extract E160c	Capsanthin, Capsurubin Beta carotene	Orange to red	Meat, soups, sauces, snacks, - de-odourised forms in dairy desserts and confectionary.	Fair to stable	Sensitive	Sensitive	Stable
Paprika Colouring foodstuffs	Carotenoids	Orange to red	Meat, soups, snacks Its use is sometimes limited due to its flavour	Fair to stable	Sensitive	Sensitive	Stable
Lycopene E160d	Lycopene	Orange to red	Dairy products where fat content is not high, soft and alcoholic drinks, sugar confectionery, marinades and surimi.	Stable	Stable	Sensitive	Stable
Carotenes E160a	Beta-carotene Mixed carotenes	Orange	Usually nature identical form is used, Soft drinks, desserts, sweets and meat products.	Stable	Sensitive	Sensitive	Stable (pH 2-8)

Orange Carrot Colouring foodstuff	Beta-carotene	Orange Yellow	Dairy fats, beverages, desserts, confectionery	Stable	Sensitive	Sensitive	Stable
Safflower Colouring foodstuff	Carthamine	Yellow	Sugar confectionery Beverages	Stable	Fair	Sensitive	Stable
Curcumin E100	Curcumin	Yellow	Dairy, ice-cream, chilled desserts, confectionery, bakery and savoury.	Stable	Very sensitive	Stable	Stable between 2 and 7 (slight green tinge at low pH)
Turmeric Colouring Foodstuff	Curcumin	Yellow	Dairy, ice-cream, chilled desserts, confectionery, bakery and savoury.	Stable	Very sensitive	Stable	Stable between 2 and 7 (slight green tinge at low pH)
Lutein E161b	Lutein	Yellow	Beverages (lemon flavoured), dairy desserts and salad dressings. Used where light sensitivity of curcumin limits use, as it is more expensive.	Stable	Stable	Moderate stability	Stable (pH 2-7)
Riboflavin E101	Riboflavin Riboflavin-5'-phosphate	Yellow	Milk products, sugar confectionery and icings	Fair stability	Sensitive	Sensitive	Stable (pH 2-6)
Chlorophylls E140	Chlorophyll	Olive Green	Ice cream, dairy, sugar confectionery, jams/jellies	Sensitive	Fair to Sensitive	Sensitive	Sensitive

Copper complexes of chlorophylls E141	Chlorophyll	Blue Green	Ice cream, bakery, sugar confectionery, jams/jellies	Stable	Stable	Fair	Stable
Nettle, Spinach colouring foodstuff	Chlorophyll	Green	Ice cream, icing	Sensitive	Sensitive	Sensitive	Sensitive
Caramels E150a, 150b, 150c and 150d	Chemical changes caused by heating sugars	Light yellow to reddish brown	E150a mainly used in alcohol and spirits. Soft drinks such as colas, cola flavoured confectionery,	Stable	Stable	Stable	Stable but plain caramel (E150a) will precipitate at low pH
Caramelised sugar syrup or burnt sugar Colouring foodstuff	Chemical changes caused by heating sugars	Brown	Soup, sauces, confectionery and desserts	Stable	Stable	Stable	Will precipitate at low pH
Barley malt extract Colouring foodstuff	Chemical changes caused by heating sugars	Reddy brown	Cola beverages	Stable	Stable	Stable	Stable
Iron oxides and Hydroxides	Iron oxide	Red to black	Sugar confectionery	Stable	Stable	Stable	Stable

Guidelines Commissioned by:

Food Standards Agency in Scotland
6th Floor St Magnus House
25 Guild Street
Aberdeen
AB11 6NJ

Tel: 01224 285100
Fax:01224 285168
Email: scotland@foodstandards.gsi.gov.uk

For more information and advice about food,
visit the Food Standards Agency website food.gov.uk

Report Author:

Sarah Chapman
Campden Technology Limited
Station Road
Chipping Campden
Gloucestershire
GL55 6LD, UK

Tel: 01386 842000
Fax: 01386 842100
www.campden.co.uk

Date: March 2011

Report No: FMT/21810/1

Campden Technology Limited, Registered no. 3836922, Incorporated in England & Wales
Registered Office: Station Road, Chipping Campden, Gloucestershire. GL55 6LD
Part of Campden BRI Group