Colouring our foods in the last and next millennium

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(Received 14 July 1999; Accepted in revised form 18 November 1999)

Summary Colour in one form or another, has been added to our foods for centuries. It is known that the Egyptians coloured candy, and wine was coloured as long ago as 400 BC. The developing food industry had available a vast array of synthetic colours in the late 1800s. This led to colours being added for decorative purposes and unfortunately to disguise low quality foods. There was no control over this use of colour and so inevitably legislation came into force. In particular this was as a result of health concerns over some of the toxic compounds used. An established list of permitted synthetic colours eventually came into force in most countries early in this century. In the last twenty years however, consumers have become increasingly aware of the ingredients in their foods and as such they require foods to be as 'natural' as possible. This combined with technological developments has fuelled the increase in the usage of naturally derived colours. Today the food industry has an extensive colour palette available, allowing selection of the most suitable colour for their application requirements. Legislation is also in place to protect the consumer. Colour suppliers are however constantly striving to improve the technical and physical properties of their colour portfolio, to make the use of colour easier, to improve the stability and to meet customer demands on the functional additives used within colour formulations. This paper will review all colours in terms of recent developments and regulations as well as addressing the question of the future of colours in the next millennium.

Keywords Functional food ingredients, market trends, natural, pigments, synthetic, regulations.

Introduction

Colour affects every moment of our lives, strongly influencing the clothes we wear, the furnishings in our homes and gardens, and the appeal of foods. Most of our colour choices are unconscious but much research has identified that the colour of our surroundings effects our moods and perception of quality.

Everyone is sensitive to the colour of foods. Appetite is stimulated or dampened in almost direct relation to the observer's reaction to colour. The colour we see clearly indicates the flavour we will taste. In terms of food manufacturing a good, for example, strawberry colour can indicate to the consumer a high quality product, whilst a washed out or artificially bright product can indicate poor quality or an inferior product.

Numerous sociological, technical and economic factors have influenced the food industry over the last 20 or so years. Over this time the food market has changed rapidly with a much larger proportion of food being 'processed' before sale and ready prepared to meet the needs of new consumers such as working mothers, single parent families and the increasing number of older people in the western world. The challenge to the food industry is to provide visually appealing foods that taste good and meet the consumers demands on quality and price.

The colour production industry aims to meet food and drink manufactures needs by providing a full range of colours to suit all applications, within current legislative constraints. There is however

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constant ongoing developments to improve the stability and handling properties of colours using formulation technology, new processing methods and to a much lesser extent (mainly restricted by legislative controls) development of totally new pigments.

This paper aims to assess all food colour materials, including those defined as artificial, natural and nature identical, in terms of market development, regulations and technical limitations. It is however beyond the scope of this paper to detail all the technical characteristics and global legislative constraints of the colours discussed.

Recent developments of new and improved colours will be reviewed in terms of current consumer concerns such as the incorporation of more natural products into food. Genetic modification is also addressed from the standpoint of colour formulation production. Finally we will identify the future outlook for colours with respect to legislation, innovations in formulation and processing technology in the constantly changing food market.

Food colours in history

The addition of colourants to foods is thought to have occurred in Egyptian cities, where candy makers around 1500 BC added natural extracts and wine to improve the products appearance (Meggos, 1995). Up to the middle of the 19th century ingredients, such as the spice saffron, from the area local to the production units were added for decorative effect to certain foodstuffs.

Following the industrial revolution both the food industry and 'processed food' developed rapidly. The addition of colour, via mineral and metal based compounds, was used to disguise low quality and adulterated foods, some more lurid examples being:

- red lead (Pb_3O_4) and vermillion (HgS) were routinely used to colour cheese and confectionery;
- copper arsenate was used to recolour used tea leaves for resale. It also caused two deaths when used to colour a dessert in 1860.

Toxic chemicals were used to tint certain candies and pickles. Historical records show that injuries, even deaths, resulted from tainted colorants.

In 1856 the first synthetic colour (mauvine), was developed by Sir William Henry Perkin (Walford, 1980) and, by the turn of the century, unmonitored colour additives had spread through the USA and Europe in all sorts of popular foods, including ketchup, mustard, jellies, and wine. Sellers at the time offered more than 80 artificial colouring agents, some intended for dyeing textiles, not foods. Many colour additives had never been tested for toxicity or other adverse effects.

As the 1900s began, the bulk of chemically synthesized colours were derived from aniline, a petroleum product that is toxic. Originally, these were dubbed 'coal-tar' colours because the starting materials were obtained from bituminous coal

Though colours from plant, animal and mineral sources, which had been used in earlier times, the only colouring agents available, remained in use early in this century, manufacturers had strong economic incentives to phase them out. Chemically synthesized colours simply were easier to produce, less expensive, and superior in colouring properties. Only tiny amounts were needed. They blended easily and didn't impart unwanted flavours to foods. But as their use grew, so did safety concerns.

This lead to numerous regulations throughout the world, which for example in the USA reduced the permitted list of synthetic colours to seven from 700 being used!

However 'adulteration' continued for many years and this, together with more recent adverse press comments on food colours and health, has continued to contribute to the consumers concern about colour addition to our foodstuffs.

Market trends

There are no reliable published statistics on the size of the colour market, however, on a global scale a reasonable estimate would be \$940m which can be segmented as in Fig. 1.

In terms of individual sector size, it is estimated that the split is:

- synthetic colours – \$400m;
- natural colours – \$250m (of which \$100m is in the USA);
- nature identical colours – \$189M;
- caramel colours – \$100M.

Consumer pressure, sociological changes, and technological advances leading to more advances in the food processing industry have increased the overall colour market. The most significant growth has been in naturally derived colours owing to the improvements in stability as well as the food industries aim to

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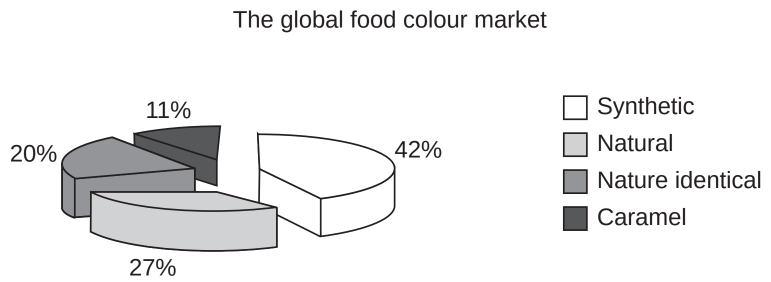

Figure 1 Percentage market share of food colours.

meet the increasing consumer perception that 'natural is best'.

Future growth is thought to be going to be greatest for naturally derived colours with a predicted annual growth rate of 5–10%. Synthetic colours are still forecast to grow but at a lower rate of between 3 and 5%.

Current regulations

The European Union member states

The use of all food additives is controlled by legislation, which is harmonized across the European Union. Domestic legislation in each member state is based on the various additive directives incorporated into the appropriate national legislation.

The framework Directive on Additives (89/107/EEC) provides the 'umbrella legislation' under which the individual additives directives are developed. It includes a definition of a food additive, exclusions from the scope of the definition and a list of food additive categories, one of which is 'colours'.

The three major detailed directives on additives are 'colours' (94/36/EC), 'sweeteners' (94/35/EC) and 'additives other than colours and sweeteners' (95/2/EC), the latter usually being referred to as 'The Miscellaneous Additives Directive'. Commission Directive 95/45/EC deals with purity criteria for colours, i.e. specifications.

The 'Colours in foods regulations 1995' implemented the 'Colours Directive' in the UK and gave a deadline for final compliance of 30th June 1996.

Colour additives are defined by these regulations and, by exclusion, foodstuffs which have colouring properties, e.g. spices, spinach, and malt extract, are not classified as colours. This area has posed some difficulties of definition where extracts of colouring foodstuffs are concerned, but the key factor is whether a selective extraction has occurred. If such extracts retain the other major components, such as flavouring, they then remain foodstuffs as opposed to additives. If, however, the colour is concentrated at the expense of removing the other components, then the resultant material becomes a colour.

The various schedules attached to the EU regulations (94/36/EC) set out the following:

- A list of the permitted colours.
- A list of basic foodstuffs to which colours must not be added.
- A list of foodstuffs in which only a limited list of colours may be used.
- A list of colours which have restricted application.
- A list of colours permitted generally *quantum satis* and colour with maximum inclusion levels for particular food categories.

Scope for amending the legislation

Whereas both the 'sweeteners' and the 'miscellaneous additives' directives have been subject to amendments, which reflect technological advances that have occurred since the development of the original directives, the colours directive has not been subject to such amendments. Indeed, there appears to be great reluctance on the part of the European Commission and the member states to initiate changes to the directive itself. The process would be slow and complicated, involving the Commission, the Council of Ministers and the European Parliament.

There has been a recent example of the introduction of a new source of colouring material mixed carotenes, E160a, produced from algae and consisting predominantly of β-carotene. Following a favourable opinion on the safety of the colour from the Scientific Committee on Food, it was necessary to modify the purity criteria for E160a (i) to include algae as a source material. This modification was put

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forward as a commission directive to the regulations and has been approved by the member states operating through the Standing Committee on Foodstuffs. Despite this being a long process, agreement was finally reached at the beginning of May 1999. This development now allows another source of carotenes to be used within the EU as well as facilitating easier US exports and imports. Until such a time as the main colours directive is amended changes will be limited to similar small modifications to the purity criteria.

Labelling of colours

Colours used in food products, like other additives, must be declared in the ingredients list by category name, i.e. colour, plus either the name of the colour or the E number. Colours present in mixtures with other additives (e.g. flavours) are not excluded from this and must be declared, because they will have a colouring function in the final product. Within the UK there tends to be a mixture of the declaration possibilities, depending on the printing area available (E numbers are shorter than names!) as well as the food manufacturers and retailers own policies. The consumer still has a negative opinion of the 'E' numbers following unsubstantiated popular press articles linking colours to unwanted behaviour in some people (mainly children) in the early 1980s and because of this many foods name the colour added.

US legislation

In the USA the use of food colours is governed by the Code of Federal Regulations (CFR). This is divided into 50 titles and title 21 is assigned to the Food & Drug Administration. Parts 70–82 list colour additives. These are divided into two categories:

- Certified colour additives – FD&C colours. These are synthetically produced organic molecules that have had their purity checked by the FDA. There are seven of these, which are water soluble dyes and six insoluble lakes.
- Colourants exempt from certification. These are derived from animal, vegetable, mineral origin or are synthetic duplicates of naturally existing colours. As such they contain complex mixtures of numerous components. There are 26 of these.

From a regulatory point of view there is no such thing as a 'natural colour'. Although, it is generally accepted that colourants exempt from certification are usually naturally derived.

Labelling of colours in the USA

In terms of labelling the terms 'natural colour' and 'food colour' are not permitted as they may indicate that the colour occurs naturally, when it doesn't. There are numerous options available: 'artificial colour'; 'artificial colour added'; and 'colour added'.

These terms do not indicate any real benefit when using naturally derived colours. A preferred option is 'coloured with x' or 'x (colour)' naming the colour source, e.g. Annatto.

If the name of the specific colour is not included the label declaration must then say 'artificially coloured or 'artificial colour added'.

Review of currently available colourants

The European Union has authorized 43 colourants as food additives with each one assigned an 'E number'. Of these, 17 are synthetic pigments and 26 are either naturally derived, synthesized to match the naturally occurring counterparts or are inorganic pigments found in nature. Directive 94/36/EC of 30th June 1994 (see previous section) harmonized all previous individual country legislation and details these colours. This was in response to the development of a single market for the free movement of goods, consumer demand for health and safety and the prevention of food adulteration

Within the UK and many European countries there has been a distinct move towards the use of natural and nature identical colours over the last 10–15 years. This has been as a result of consumer and major retailer pressure to develop more natural products and the limitation on the inclusion of synthetic colours in food has been enforced by legislation. As we reach the end of a century and enter a new millennium this impetus is increasing, in line with an increase in 'organic foods' and the consumer's current fear of adulterated, albeit safe under European regulations, foods. Many retailers are now restating their aims to provide more natural foods, which they initiated more than ten years ago. Recent developments are now making this a distinct possibility rather than an aim.

There will always be a market for synthetic colours. The food market is very diverse and the

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constant need for cost effective, readily available foods such as 'value' brands coupled with a major increase in the number of people eating in restaurants (where ingredients used are not declared) means artificial colours will continue to be used in substantial quantities. There is still only one way to achieve a stable blue shade with the possibility of widespread application and few technical limitations (such as pH) and that is, of course, by using synthetic colours.

In the USA, certified (i.e. synthetic) colours have historically been used, mainly because of the range and shade achievable, the low cost and the good stability. Synthetic colours are also highly concentrated, there are also no limits on dosage level, and they are widely available. However, there is a growing move towards natural products and growth in the 'natural colour' market is predicted, especially as owing to the fact that only seven synthetic colours are approved.

Synthetic colours

Currently the seven permitted synthetic pigments in the USA (prior to 1906 the USA 'adulterated' foods with more than 700 colourants, many of which were highly toxic!), compares with the 17 permitted synthetic pigments within the EU. These are all in the form of water soluble dyes. Lake pigments and dispersions are also permitted of which there are six in the USA (the lake of erythrosine is not permitted because of concerns over its iodine content).

Water soluble dyes were originally produced as fine powders. These have proved problematic to customers in terms of dusting and clumping. Suppliers have addressed this problem by making granules, pre-weighed sachets and gels (Madkins & Schaefer, 1998).

Lake pigments are insoluble precipitates onto an 'aluminium hydrate substrate' and are produced as extremely fine powders. The dye content and particle size determine the colour shade of the powder. Lakes are primarily used when:

- there is insufficient solvent to dissolve the dyes (for example in fat based applications);
- when colour migration is a problem;
- when an ultra fine powder is required (for example in powdered desserts and soups to colour the dry mix);
- in confectionery for coloured panned sugar coatings (such as that used for 'Smarties'), providing less drying time and a more even coating than water soluble pigments.

Lakes tend to be more stable to light and other chemicals than their parent dyes, but are usually unsuitable in strongly acidic products as the colour–aluminium bond is broken down, resulting in delaking and colour change/precipitation problems. Liquid dispersions are also made of lake pigments for the ease of handling and customer preference. Table 1 details all synthetic pigments, their colour shades and key properties.

Although cited as having excellent stability, soluble dyes do lose colour in certain food manufacturing circumstances. The most common problems with soluble dyes are:

- decolourization by ascorbic acid (vitamin C);
- loss of colour resulting from microbial attack (often used as an indicator for 'off' foodstuffs);
- precipitation/colour loss resulting from the presence of metal ions;
- reaction with proteins at high temperature causing colour fade.

These problems are difficult to overcome without chemical modifications to the pigments, which is not permitted. Colour suppliers offer technical support to recommend the most suitable dye for the application, as well as advice on the stage of addition and other ingredients such as sequestrants and antioxidants that can be added to reduce colour loss.

Nature identical colours

'Nature identical' colours have been developed to match their counterparts in nature. The most common pigments that are synthesized are carotenoids consisting of conjugated hydrocarbons, and as such they are prone to oxidative attack and a subsequent loss of colour. Colour formulations have been developed with antioxidant systems (for example tocopherol and ascorbyl palmitate), to reduce this effect. Table 2 details the key properties of the main nature identical colours.

'Nature identical' β-carotene has a large portion of the colourant market (around 17% of the global and 40% of the European market, the annual output is thought to exceed 500 tonnes) and was first marketed in 1954. Its principal use is in yellow fats (margarines, low fat spreads etc.), soft drinks,

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Table 1 Key features of synthetic colourants

Pigment	Colour shade	USA name	EU code	Comments
Brilliant blue	Turquoise blue	FD & C Blue 1	E133	Fair light and acid stability. Poor oxidative stability
Indigo carmine	Royal blue	FD & C Blue 2	E132	Poor light heat and acid stability. Poor oxidative and SO_2 stability. Faded by ascorbic acid
Erythrosine	Bright pink/red	FD & C Red 3	E127	Insoluble below pH 5. In EU only permitted in cocktail, candied and Bigarreaux cherries. Lake colour is delisted in the USA. Restrictions owing to iodine content
Allura red	Orange/red	FD & C Red 40	E129	Good light, heat and acid stability. Most recently approved FD & C colour. Most stable red to ascorbic acid in soft drinks
Tartrazine	Lemon yellow	FD & C Yellow 5	E102	Excellent light, heat and acid stability. Fades with ascorbic acid and SO_2. Implicated in food intolerance studies
Sunset yellow	Orange	FD & C Yellow 6	E110	Good light, heat and acid stability. Fades with ascorbic acid and SO_2
Fast green FCF	Sea green	FD & C Green No.3	Not permitted	Fair stability to light and heat. Poor stability to oxidation
Amaranth	Magenta red	Not Permitted. Delisted in Feb 1976	E123	Good light, heat and acid stability. Fades with ascorbic acid and SO_2. In EU application restrictions apply
Carmosine	Red	Not Permitted	E122	Good light, heat and acid stability
Ponceau 4R / Cochineal red A	Strawberry red	Not Permitted	E124	Good light, heat and acid stability. Some fading with ascorbic acid and SO_2
Red 2G	Bright pink	Not Permitted	E128	Good light, heat and acid stability. No fading with ascorbic acid and SO_2. Restricted application use in EU
Patent blue V	Turquoise blue	Not Permitted	E131	Excellent light and heat stability. Faded by acids and SO_2
Green S	Greenish blue	Not permitted	E142	Good heat and acid stability, but moderate light stability
Brown HT	Chocolate brown	Not Permitted	E155	Good heat, light and acid stability. Maximum dose levels enforced in EU mean rich chocolate colours no longer achievable
Brown FK	Red-brown	Not Permitted	E154	Only permitted in kippers
Brilliant black BN	Violet black	Not Permitted	E151	Good light stability. Poor heat stability
Iron oxides Yellow, red, black	Red, yellow, Black	CFR 73.200 Synthetic Iron Oxides	E172	Excellent stability to heat, light pH and oxidation. In the USA only permitted in dog & cat food
Quinoline yellow	Lemon yellow	D & C Yellow 10 similar but not the same	E104	Good heat, light and acid stability
Aluminium/ silver/gold	As pigment	Not listed.	E173 , E174, E175	Inorganic pigments used for decoration purposes
Lithol rubine BK	Orange/red	D & C Red No.7 (not permitted in food)	E180	Permitted only in the EC for cheese rind. Oil dispersible

confectionery and bakery products. Two main manufacturers supply NI β-carotene, Hoffman la Roche (Basel, Switzerland) and BASF (Ludwigshafen, Germany), within their vitamin portfolio. For most food and drink applications the challenge to these suppliers is to provide oil and water dispersible forms (especially for the yellow fat and soft drink markets). This is achieved using methods such as emulsification and pigment suspension as follows (BASF, 1997):

- Emulsion formulations consist of very fine β-carotene containing oil droplets dispersed throughout an aqueous phase. These can be spray dried to give water dispersible powders.
- Oil dispersible suspensions are made using micronization to form nano sized β-carotene crystals

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Table 2 Key features of nature identical food colours

Colour	Shade	Comments
β-Carotene (E160a)	Yellow to Orange depending on colour formulation	Sparingly oil soluble, consisting of principally of the all trans isomers. β-carotene has pro vitamin A activity
Beta-apo-8′-carotenal (E160e)	Reddy Orange	Sparingly oil soluble, consisting of principally all trans isomers. Used in application in combination with β-carotene. Has vitamin A activity, but at a lower level than β-carotene
Ethyl ester of beta-apo-8′carotenic acid (E160f)	Yellow / Orange	Oil soluble. Used as a marker for intervention butter & chicken feed applications (LFRA, 1997) Has vitamin A activity, but at a lower level than β-carotene
Riboflavin & Riboflavin 5′ Phosphate (E101 (I & ii)).	Yellow	Slightly water-soluble also vitamin B2. Sensitive to light causing colour fading
Canthaxanthin (E161g)	Orangy Pink	Only permitted in Saucisses de Strasbourg. Occurs naturally in salmon, shrimp and flamingos

suspended in vegetable oil. Dispersing this suspension through a protective colloid–polymer matrix, which coats and stabilizes the pigment, makes water dispersible beadlet forms. This suspension is then spray dried to form high strength powders.

By using these methods water and oil dispersible nature identical colours with pigment contents from 1 to 10% have been developed. The shade achieved is dependent on the formulation and processing used and varies from golden yellow to a red/orange shade.

Natural colours

Significant developments have occurred with natural colours since their wider commercialization around 25 years ago. The growth in use of natural colours comes from increasing consumer pressure for 'natural' products in light of their distrust for the food industry, based on unsubstantiated health scares related to additives in general, but especially related to hyperactivity and its perceived association with many azo dyes such as tartrazine.

Colour is spread widely throughout nature in fruit, vegetables, seeds and roots. In our daily diets we consume large quantities of many pigments, especially anthocyanins, carotenoids (nature is thought to produce in excess of 100 million tonnes per annum of carotenoids, of which more than 600 structures have been identified) and chlorophylls. Our intake from naturally coloured processed food is fairly insignificant when compared to this.

Pigments from nature vary widely in their physical and chemical properties. Many are sensitive to oxidation, pH change and light and their inherent solubility varies widely.

There are currently 13 permitted naturally derived colours within the EU and 26 colours exempt from certification in the USA. Table 3 details the colour shade and key characteristics of the most commonly used, permitted naturally derived colours.

Other colours exempt from certification within the USA are; Ultramarine blue (limited to animal feed), toasted partially defatted cooked cottonseed flour, ferrous gluconate, dried algae meal (limited to chicken feed), carrot oil and corn endosperm oil (limited to chicken feed). These have limited use either because of an application restriction or poor stability.

Natural colours were initially considered much less stable, more difficult to use and more expensive than the synthetic colours they aimed to replace. It was always thought the colour shades achievable would be less vibrant and appealing.

It is estimated that world wide up to 70% of all plants have not been investigated fully and that only 0.5% have been exhaustively studied (Wissgott & Bortlik, 1996). From this it could be concluded that we have only just begun our search for natural food colour sources. Unfortunately, however, most pigments fall into the classes mentioned above, making minor pigment classes rare. Any totally new pigment source would require safety assessment, which would be costly and time consuming, prior to any FDA petitioning and EU approval for use as a food

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Table 3 Key features of naturally derived colours

Pigment	Sources	Colour shade	Comments
Curcumin	Turmeric Rhizome (roots) – India	Bright lemon yellow	A non soluble pigment that is light sensitive once solubilized and in the presence of water Used widely in desserts and confectionery
Lutein	Tagetas Erecta (marigold) and Alfalfa	Golden yellow	Oil soluble carotenoid pigment naturally present in many foods. The development of easy to use water soluble forms with increased oxidative stability has extended its use to applications such as desserts, soft drinks and bakery products. Only permitted in the USA in chicken feed
Natural mixed carotenes	Palm oil, *D.salina* (algae)	Golden yellow to orange	Another oil soluble mixture of carotenoids (principally β-carotene), which is naturally sensitive to oxidation. The USA permits only the algal source. Has pro vitamin A activity
Bixin/norbixin	Bixa Orellana bush seeds – South America	Orange	Bixin is oil soluble and norbixin water dispersible. Initially widely used in the EU as a natural colour. Use is now restricted. Widely used in ice cream, cheese, yellow fats and smoked fish. No restriction in the USA
Capsanthin/ capsorubin	Paprika *Capsicum annum L.*	Reddy orange	Naturally oil soluble carotenoids from the red pepper. The flavour level (capsaicin) must be lower than 250 p.p.m. in the EU. Used in savoury products such as sauces and coatings as well as desserts, confectionery and bakery products
Lycopene	Tomatoes	Orangy red.	Naturally oil soluble carotenoid pigment. Has found little commercialization as a colour owing to high cost, poor stability and orange rather than red shade. Also not listed in the USA as a colour additive
Carminic acid	Cochineal insect (female) – Peru	Orange to red	Water dispersible pigment with colour shade becoming more red with increased pH. Price sensitive owing to cultivation method (hand picked). Approximately 70,000 insects are needed to produce 500 g of 50% strength pigment
Carmine	Cochineal insect (female) – Peru	Pink to red	Carmine is the aluminium lake of carminic acid. Produces very stable pink/red shades. In acidic products delaking can occur resulting in colour change and precipitation. Widely used in confectionery and savoury products. As with carminic acid limited to 'non vegetarian' foods
Betanin	Red table beetroot	Pink to red	Water soluble pigments that are degraded by prolonged heating. Widely used in ice cream and desserts
Anthocyanin	Black grapeskin, elderberries, black carrots, red cabbage.	Pink/red to mauve/blue depending on pH	Natural pigments of many red fruits, flowers and vegetables. Largest commercial source is grapeskin (v. vinifera) as a byproduct of the wine industry. Widely used in soft drinks to depict blackcurrant flavoured products.
Chlorophyll (in)	Grass, lucerne and nettle	Olive green	Chlorophylls are oil dispersible and chlorophyllins water soluble. Limited use owing to poor stability and dull colour shade. USA permitted source is as a vegetable (e.g. spinach) extract
Copper chlorophyll(in)	Grass, lucerne and nettle	Bluish green	Exchange of Mg^{2+} at the porphorin centre for Cu^{2+} leads to bright stable shade. Not listed in the USA
Carbon black	Vegetable material	Grey to black	Insoluble black pigment with excellent stability. Widely used in confectionery. Not listed in the USA
Crocin	Saffron/ Gardenia fruit	Yellow	Water soluble carotenoid pigment. No longer listed in EU. Further safety testing is required. Saffron is listed in USA but is limited by its high cost
Titanium dioxide	Anatase	White	Insoluble white colour derived from nature by various processes. Used to add whiteness to confectionery and bakery decorations. Also used for low fat products to add creaminess

colourant. The final drawback is that many 'undiscovered pigments' will be in unprospected land or the sea and commercialization could be an uneconomic prospect.

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With these drawbacks in mind suppliers of natural colours have focused the development on currently permitted pigments in three main areas: formulation technology, processing technology; and alternative sources of pigments.

These approaches have proved very successful and have contributed to the increase in usage of natural colours throughout the food and drink industry. Food manufacturers are now confident that a colour supplier can produce most colour shades in a natural form giving the vibrancy, stability and usage characteristics they require.

Caramel colours

Caramel colours form a significant segment of the overall colour market (around 11%), principally owing to their use in cola beverage drinks. They are produced by the controlled heating of carbohydrates such as sucrose, glucose and fructose. Four classes of caramels are commercially produced for specific applications. They differ in the catalyst used to promote the caramelization process. Table 4 details these four caramels and their application areas.

The market for caramel colours is thought to be reasonably static, with annual increases at around 2–3% per annum. It is thought growth will occur through market development and in line with the predicted growth in 'brown' food products such as toffee flavoured products, colas and ready meals.

Recent developments in colours

Formulation

Developments in colour formulation over the last 5 years have focused on augmenting the stability of natural and nature identical pigments, as they have much variation in their natural stability and solubility. Improvements in synthetic colours have focused around process developments. Additives used in natural colour formulations can have a major effect on the colours' stability, ease of use and colour shade. Additives can also affect the finished application characteristics.

Formulation developments have focused on improvement in four main areas:

- Making water dispersible forms of naturally oil soluble pigments by forming a dispersion of oil solubilized pigments throughout an aqueous disperse phase, using emulsifiers, antioxidants and stabilisers.
- Enhancing stability to oxidation via the synergistic use of antioxidants such as tocopherols and ascorbyl palmitate.
- Improved acid stability and clarity for applications such as soft drinks, jellies and conserves.
- Replacement of consumer 'unfriendly' (often allergenic) ingredients such as peanut oil and potential genetically modified ingredients such as maize and soya derivatives.

Overseal Foods Ltd. (Swadlicote, UK) have developed the Em-Seal® range of water dispersible emulsions based on the pigments natural carotene, lutein and paprika. Various emulsifying systems are used depending on the final application. These colours are characterized by excellent dispersibility and improved oxidative stability giving a stable, bright and easy to use yellow through to orange/red shades, for a range of food and drink applications.

Applications such as jellies, confectionery and certain beverages require bright stable colours with excellent clarity. Pigments that are normally oil soluble, such as carotenes and paprika, can produce slightly hazy colours once emulsified. This is over-

Table 4 Key features of caramel colours

Caramel	EU code	Catalyst	Application areas
Plain or spirit caramel	E150a	With / without acid / alkali	Designed for high proof spirits
Caustic sulphite caramel	E150b	Sulphite containing compounds	Stable to ethanol and tannins used in alcohol such as Martini
Ammonia or beer caramel	E150c	Ammonia	Most widely used (>90% of food applications). Positively charged
Sulphite ammonia or soft drink caramel	E150d	Ammonia and sulphite containing compounds	Used principally in Cola drinks and accounts for significant volume. Has emulsifying properties

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come by the formation of microemulsions in emulsifiers such as polysorbate. Examples are the Clear-Col™ emulsions from Overseal Foods Ltd which offer crystal clear carotenes and paprikas with excellent oxidative and acid stability.

Most recently developments with nature identical colours have focused around the removal of the functional peanut oil and bovine gelatine ingredients, allowing larger customer acceptance by removal of possible allergenicity concerns. Corn oil has been used to replace peanut oil and fish gelatine has replaced bovine gelatine, the latter move has been followed by kosher approval.

A new 7% CWS (cold water soluble) beadlet formulation has recently been developed by Hoffman la Roche (Ruijter, 1998). This provides an intense yellow shade (the 10% beadlet formulation is more orange) and an almost translucent dispersion. The formulation consists of fine β-carotene crystals in a matrix including corn oil, fish gelatine, maltodextrin, sucrose and silicon dioxide with the antioxidant benefits of ascorbyl palmitate and dl-∝-tocopherol. Application areas include soft drinks, confectionery and dairy products.

Process

Processing technology has had a significant beneficial effect on both natural and synthetic colours.

Milling of pigments to encapsulate them into an insoluble carrier has produced a range of suspensions with improvements over their solubilized counterparts. This technology has lead to benefits for natural pigments such as:

- Improved light stability (for example with curcumin), extending its areas of application to products such as sauces, dressings and soft drinks (Hansen, 1999).
- Oil dispersible forms of naturally water dispersible pigments for example beetroot extract and caramel.
- A reduced level of certain additives, for example the emulsifier polysorbate 80, which has some legislative restrictions (i.e. for the Japanese market) and can cause problems in some food applications such as foaming and interactions with extruded applications such as breakfast cereals (Boyd, 1998).
- Production of different colour shades from those normally exhibited by the solubilized pigments. Curcumin becomes more of a golden yellow shade and carmine can produce shades from candy pink to mauve.
- Less colour migration in applications such as desserts, when a fruit preparation is layered with a pH neutral diary base.

Advances in spray drying combined with ingredient/formulation technology has lead to the development of some microencapsulated natural pigments. High DE (Dextrose Equivalent) maltodextrins have been used to improve the stability of carotenoid pigments (Desobry, 1998) such as mixed carotenes and annatto.

With synthetic pigments process developments have focused around producing 'low dust' granular dyes. Traditionally dyes were manufactured in solution, precipitated and filter pressed. The press cake was dried and ground to a powder. Granules of a sort were produced from this cake which suffered from poor dispersibility and had a limited dust reduction. Extrusion technology has more recently been used to produce 'vermicelli' type granules, which have lower dusting properties but can suffer from flow and dispersion problems as well as breaking up in transit. Granulation technology has most recently been used for both synthetic and natural pigments. By agglomerating the pigments into granules the colours flow well, have low dust properties and have a high surface area for ease of dissolution.

Pigment sources

One of the major limiting factors in developing totally new colour formulations is the lengthy and costly safety testing and regulatory approval process. A successful approach to new natural colours has been to use alternative previously 'untapped' sources of raw materials for pigments that conform to the current regulations.

Black carrots have been used as a source of anthocyanin based pigments. The commercialization was pioneered by Overseal Foods Ltd under their brand name Carantho® (Collins & Stich, 1998). The interest and success of black carrot based anthocyanins lie in the fact that they:

- Provide an excellent bright strawberry red shade in acidic products such as soft drinks, conserves, jellies and confectionery.
- Offer improved stability to heat light and SO_2 over

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more traditional anthocyanin sources such as grapeskin or elderberry. This is because of the presence of acylated anthocyanins.
- Offer consistent year round supply.
- Contain low levels of polyphenols, which are naturally present in grapeskin anthocyanins and which can cause hazing and precipitation problems.
- Provide wider global acceptance in terms of being kosher approved, suitable for vegetarians and being more widely applicable in the USA (as vegetable juice).
- Can be used as a vegetarian replacement for carmine in many low pH applications.
- Provide more stable mauve/blue shades at more neutral pH values.

One recent development has been to exploit a 'bluer black carrot' variety. Once extracted the anthocyanins present exhibit a more 'blackcurrant flavour' shade than the original carrot source. Blue black carrot anthocyanins offer all the high quality, stability and global acceptance benefits of the red source but with a shade that offers an excellent alternative to grapeskin anthocyanins, which can suffer from quality, shade variation and availability issues.

Another recent development has been to improve the extraction of natural pigments currently permitted to provide more suitable colour extracts. An example is the extraction of anthocyanins from red cabbage (*Brassica oleracea*). Red cabbage anthocyanins provide very stable bright raspberry pink shades at low pH, mauve to purple shades at around pH 5–6 and stable blue shades at pH 7–8. Historically the extraction process concentrated undesirable sulphur containing compounds resulting in an unpleasant odour in the colour, which was often detected in the finished application. Recent improvements in the extraction process have lead to fully deodorized red cabbage colours. This exciting new development extends the pink/mauve shades available to food manufacturers with the benefit of being from a natural source.

Other permitted sources of anthocyanins are also under evaluation. Research into acylated anthocyanins, with enhanced stability (as in black carrots and red cabbage) is ongoing from sources such as purple and red potatoes (Rodriguez-Saona, 1998) (*Solanum tubersom*) as well as red raddish.

As mentioned earlier, an algal source of natural mixed carotenes has very recently been approved for use within the EU. The algal source is used as a colour and health supplement in Australia and the USA. This development now means that an alternative natural carotene source can be marketed globally giving golden yellow to orange shades.

A nature identical version of lycopene, the natural carotenoid pigment present in tomatoes, has recently been launched by BASF. As a food colour the EU purity criteria states the source material must be tomatoes and in the USA lycopene is not listed as a colour. Nature identical lycopene would therefore have to be added as a functional food ingredient which has a secondary colouring effect, or be subjected to a safety assessment procedure to approve its use as a food colour.

Additives in additives

This is a major area for development activity with respect to food colours, because additional functionality can be imparted to a given pigment by using such functional additives/ingredients. An example of this is the acid stability conferred to annatto by mixing it with a polysorbate emulsifier.

An alternative approach is to use a functional additive in association with a specific process, for example an oil soluble pigment can be rendered water dispersible by using an emulsifier in conjunction with high pressure homogenization.

Additives or ingredients are usually used in a colour formulation to fulfil a technological need, the most important being;
- as a carrier or diluent;
- to impart functionality such as water/oil dispersibility;
- to improve stability in application;
- enhancement of shelf life.

At a molecular level the stability of a specific pigment is dictated by its chemical structure and the environment to which it is exposed, for example the various carotenoid pigments that are susceptible to oxidation. Chemical modification to enhance performance/stability is not acceptable, consequently the route to improved performance (e.g. enhanced stability, improved dispersibility, micro environment protection) is via the use of process and/or formulation technology.

From a regulatory standpoint there are three fundamental approaches to this issue. Firstly, the

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use of a carrier/diluent is permitted according to the miscellaneous additives directive. Secondly, the use of food ingredients (e.g. sugar, oil), whose use is not restricted by additive regulations, and finally the use of a processing aid having an impact on the colour formulation, but no technological function in the finished foodstuff. This area is not within the current regulations, although this is expected to change at some point in the future.

Formulations for soft drink/beverage applications

The soft beverage industry accounts for a significant volume of food colours sold. This is based on the fact that colourful drinks are more appealing and they enhance the consumer's perception of flavour, fruit content and overall quality. All categories of colour are used; synthetic, nature identical, natural and caramel colours (for cola). Colour problems within the industry are mainly cited as:

- Colour fading/browning with the addition of ascorbic acid (vitamin C). This effect happens with red synthetic colours such as ponceau 4R and anthocyanin based natural pigments.
- An unsightly orange/brown oily ring at the neck of principally orange 'dilute to taste' drinks. This is attributed to the pigment (mainly β-carotene) suspension/emulsion breakdown and the gradual migration of the colour oil phase combined with other oils, such as citrus flavour oils, to the surface of the drink. This can be coupled with pigment crystallization once the suspension/emulsion has broken down.
- Colour fading with SO_2.
- Poor acid stability of pigments such as carmine and copper chlorophyllin leading to precipitation.

The colour industry has focused much research and development effort into overcoming these problems by:

- Investigating alternative anthocyanin sources that are less susceptible to ascorbic acid degradation and advising on the addition of a low level of SO_2 (around 50ppm) to preferentially react with the ascorbic acid degradation products (peroxide).
- Advice as to the best production methods for using carotenoids, such as use of nature identical β-carotene, by preparation of a stock solution to release the colour together with pre homogenization with any flavour oil/concentrate component.
- Using ascorbic acid as an antioxidant to prevent colour fading with carotenoids.
- Developing special colour emulsion/suspension formulations using acid stable emulsifiers and synergistic antioxidant systems.
- Developing more acid stable copper chlorophyllin colours by further solublizing of the pigment.
- Increasing the acid stability of carmine using microencapsulation technology.

Colour formulations using ingredients from genetically modified sources

The issue of genetic modification (GM) has caused significant consumer alarm. Retailer pressure and lack of firm legislation has forced food manufacturers to redevelop whole ranges of food products containing ingredients from GM free sources. The ingredients most effected are based on soya and maize and are widely used throughout the food and drink industry in the form of carriers, emulsifiers, stabilizers and thickening/gelling agents.

Ingredients from these sources are often used as additives to add functionality to colour formulations, examples being soya or corn oil, maize derived glucose syrups and the emulsifier soya lecithin. Ingredients and processing aids are also used during the extraction process of many pigments (for example antioxidants) which could be derived from potential GM sources.

In response to different retailer and food manufacturers policies the colour industry is now aiming to remove any ingredient which is derived from a source reported to be implicated as GM, such as soya and maize. This has resulted in a colour formulation redevelopment, mainly within nature identical and natural colours. The redevelopment can start at the extraction stage (with anti oxidants and carrier oils) and continue through to the formulation development with emulsifiers and diluents. This is an area of ongoing activity, which will continue. The concern is that the replacement additives available are becoming more restricted, which could limit future developments. It is possible that few non GM crops will be available in 5 to 10 years. However it is unlikely that the consumer alarm will be at the same levels at that time, and who could predict the level of consumer acceptance on this issue.

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Organic colours

Organic foods are considered to be a growing market that has extended from the expensive and relatively unattractive fruit and vegetables of the early 1990s to a whole host of prepared foods. Organic legislation states that 'organic foods' need to contain a minimum of 95% organic ingredients by weight. The regulations list the only non organic ingredients that can be used but no colours are included. Colour can only be added via an organic source of a fruit/vegetable such as an organic juice. Manufacturers have however used natural colours and applied for a derogation to market as an 'organic' product a food product containing the colour. This process takes around 6 months.

Colouring foodstuffs

The topic of 'colouring foodstuffs' or ingredients that have a secondary colouring effect, can always be guaranteed to generate a debate and strong opinions, mainly with regard to definition and labelling correctly. As an issue it only relates to natural colours, and in practice there are two extremes;

- Use of a 'colouring foodstuff' that happens to be highly coloured (e.g. spinach juice) and which has not been selectively extracted to enrich the colour.
- A selectively extracted magnesium chlorophyll derived from spinach, which is clearly a colour additive (E140).

The difficulty lies in deciding where the line is drawn between these two extremes, and in this respect there are two main drivers; the interpretation of the regulations, including labelling and the custom and practice in individual countries.

Both approaches to the colouration of food have merits, for example 'colouring foodstuffs' may have more consumer appeal whereas using a selectively extracted colour additive can offer enhanced performance, consistency and avoidance of undesirable flavour carryover.

It remains the responsibility of the colour producer and the food manufacturer to decide on the most appropriate approach in specific circumstances.

Safety assessment

The fundamental principle in this respect is to ensure that consumer safety is not compromized. This equally applies to all additives and is a consideration that is taken without preference over one type of colour or another. It is beyond the scope of this paper to review the approval process, but suffice is to say that where deemed necessary (by the commission) a scientific investigation undertaken by the Scientific Community For Foods (SCF) in an advisory capacity takes place, leading in most instances to the provision of an acceptable daily intake (ADI),as listed in Table 5.

When considering future developments consideration needs to be given to the demands imposed on the industry by any changes to the regulations with respect to safety issues. As a general principle existing colours need to receive adequate support, because new replacements are fairly unlikely.

The most topical example is annatto E160b, which is currently undergoing a reassessment (sponsored by the colour industry on a global scale) to address the rather low ADI set many years ago, based on low test levels used in the initial assessment.

This is expected to be a general issue for additives in that where the assessment was performed a long time ago then a reassessment may be deemed appropriate. There is expected to be extra impetus in this area as all additives are due for an intake assessment, which will identify certain candidates for closer scrutiny.

Biotechnology

Biotechnology could allow the efficient mass production of colourants (Pattnaik, 1997). Plant cell and tissue culture, microbial fermentation and gene manipulation have all been investigated with respect to pigment production. However, extensive safety testing of such products would be required before they are given clearance as safe food additives. There is also the obstacle of research and development investment and manufacturing facilities.

Plant tissues are often considered to be an effective alternative method for the production of natural pigments (Cormier, 1997). Carotenoids, anthocyanins and betalains have already been produced in plant cell cultures. Continuous production using currently available techniques appears to be impossible because most pigments are not excreted by the cells but stored within them. To date no food grade pigments have been shown to be producible in large scale plant cell culture processes. Thus the develop-

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Table 5 ADI's for all EU approved colours

E Number	Colour	SCF ADI (mg/kg body weight/day)	E Number	Colour	SCF ADI (mg/kg body weight/day)
100	Curcumin	A	155	Brown HT	3
101	Riboflavin	A	160a	Carotenes	A
101a	Riboflavin –5-Phosphate	A	160b	Annatto extract	2.5
102	Tartrazine	7.5	160c	Paprika Oleroresins (Capsanthin, Capsorubin)	
104	Quinoline yellow	10	160d	Lycopene	A
110	Sunset yellow FCF	2.5	160e	Beta-Apo-8′-Carotenal	5
120	Carmines (Cochineal)	5	160f	Beta-Apo-8′-Carotenal Ester	5
122	Azorubine	4	160g	Canthaxanthin	0.03
123	Amaranth	0.5	161	Xanthophylls	A
124	Ponceau 4R	4	161a	Flavoxanthin	Covered by E161
127	Erythrosine	0.1	161b	Lutein	Covered by E161
128	Red 2G	0.1	161c	Cryptoxanthan	Covered by E161
129	Allura red AC	7	161d	Rubixanthin	Covered by E161
131	Patent blue V	15	161e	Violaxanthin	Covered by E161
132	Ingotine, indigo carmine	5	161f	Rhoxanthin	Covered by E161
133	Brilliant blue FCF	10	162	Betanin/beetroot red	A
140	Chlorophylls	A	163	Anthocyanins	A
141	Chlorophyll Chlorophyllin copper comp	15			
142	Green S	5	170	Calcium carbonate	NS
150a	Caramel colour I (plain)	A	171	Titanium dioxide iron oxides and hydroxides	A
150b	Caramel colour II (caustic sulphite)	AT	172		A
150c	Caramel colour III (Ammonia)	200	173	Aluminium	A
150d	Caramel colour IV (Sulphite–Ammonia)	200	174	Silver	A
151	Brilliant black BN, Black PN	5	175	Gold	A
153	Vegetable carbon	A	180	Lithol Rubine BK	1.5
154	Brown FK	0.15			

Key: A = Acceptable; AT = Temporarily Acceptable; NS = ADI Not specified i.e. not limited NA = ADI not allocated.

ment seems to be worth pursuing only in the case of plants that cannot be successfully cultivated or propagated. The pigments isolated from cell cultures would also display the same instability as those isolated from naturally grown plants.

Single cell algae and fungi are better options for new biotechnologically derived colourants. One recent development has been with the β-carotene from the fungus *Blakeslea. trispora.* Carotenes are produced by fermentation in a reactor. This is currently being marketed as a natural food colour by Gist Brocades (DSM Gist Brocades Delft, Heerlen, The Netherlands).

Future outlook

The aim of colour manufacturers, whether the colour be synthetic, nature identical or naturally derived is

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to constantly support and train the food industry in the correct selection and application of colour. The addition of colour is often thought of as 'last on the list' in the development process. Time pressures and ingredient rationalization often mean that the most suitable colour is not used, which can cause problems in the future, both in manufacturing, lack of consumer appeal and potential new product failure. Colour suppliers will continue to mirror the flavour industry by offering bespoke formulations and pre blends along with a comprehensive technical advice and sample service.

Regulations

Future developments in EU legislation

Undoubtedly at some time in the future the colours directive will be subject to amendment, but this seems a distant prospect at present.

The current preoccupation with GM foods is resulting in two potential changes affecting additives.

A proposal is already under discussion, which will enforce the need for food additives developed from a new source material to be subjected to review by the Scientific Committee on Food. New sources of starting material will include GM crops and as time goes on is likely to include some colours. The extent of such an evaluation is unclear at present, as discussions are still at an early stage, but it seems eminently sensible that new source materials or new production processes (this may affect the fermentative source of β-carotene) should require a safety evaluation.

Another proposal, which is expected, is that compulsory labelling of GM ingredients will be extended to food additives, including colours, if they are derived from GM sources.

There is an undertaking in the Colours Directive that the European Commission should report to the European Parliament within 5 years of the adoption of the directive, i.e. by 30th June 1999, on changes in the colours market and levels of use and consumption. The deadline will not be met but the impression is that the UK is more advanced in this exercise than the majority of member states. It is not yet clear whether consumption patterns will confirm that intakes of colours remain within acceptable limits. The exercise has the potential to provoke amendments to the Colour Directive if any high intakes are found.

Future developments in US legislation

A petition has been made to the FDA to approve D & C Yellow 10 (similar to quinoline yellow) and D & C Red 28 (Phloxine B, Purified) as food colours. Both are currently used in drugs and cosmetics. It is anticipated however that the approval will take some time.

Novel pigment sources

Many novel pigment sources have been identified as potential new sources of natural colours (Francis, 1987). Some are currently used in certain countries but unfortunately approval as an EU/US food colourant would involve lengthy and expensive safety testing, which prohibits their commercialization.

Monascus is a heat stable red and yellow colourant derived from the fermentation of rice from the fungus *Monascus purpureus* and *Monascus anka*. It is one of the most commonly used natural colours in Japan and the Orient for applications such as meat and fish. It is not permitted within the EU or the USA owing to concerns over potentially toxic coumarin compounds produced during the fermentation process.

Spirulina sp. contains the pigment phycocyanin. This gives a blue shade and has the highest stability at pH 5–7. It is not permitted as a colourant source within the EU or the USA. The FDA has classified *Spirulina* sp. as a cyanobacteria and considers it a food, not a vegetable, and as such it does not conform to the regulation 21CFR 73.260 on 'Vegetable Juice'. It is, however, used in Japan. The application areas are limited to non acidic foodstuffs such as chewing gum and dairy products.

Other sources of pigments include blue gardenia, the traditional orange carrot and purple corn which are limited by stability, price and legislation.

Formulation and process

Microencapsulation of pigments encompasses both formulation and process technology. There has been some developments within this area from all colour suppliers in both the nature identical and natural colour field. Complete microencapsulation aims to totally entrap the pigment particles in a protective network, which isolates and stabilizes the pigment from the common factors that can cause colour loss or change such as oxidation or acidic conditions.

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The release mechanism is often more of a limitation with colours than with other ingredients, such as flavours. It is the visual appearance of the food at the point of purchase, or prior to consumption, which really matters. Release in the mouth or during food processing may not always be appropriate (Plumbly & Collins, 1997).

The protection provided by encapsulation depends on the encapsulating matrix, efficiency of coating and the point in time when the pigment is released. The inner core material may be released on addition of water, heating or fracturing. If the pigment is not released the encapsulating material must be transparent to light and the microencapsules very small.

A range of encapsulating materials are suitable for colours such as carbohydrates, gums, phospholipids and proteins. Consideration has to be given to the source of these materials, for future marketing success they must be GM and nut oil free as well as kosher and suitable for vegetarians. Encapsulating methods available include spray drying, spray coating and spinning disc technology.

Microencapsulation is an area of great potential in the protection of synthetic, nature identical and natural pigment and continued advances in ingredient and processing technology should see a vast array of stabilized colours in the future.

Functional food ingredients

There is growing evidence that many food components perform additional beneficial functions in the body. Our instinctive preference for eating naturally occurring coloured (for example fruits and vegetables) over bland foods is thought to be natures' way of providing our diet with certain phytochemical compounds along with any micronutrients and vitamins naturally present. Natural antioxidants are now thought to possibly prevent the increasing incidence of many western diseases such as cancers and heart disease, thus these diseases have been linked to a lack of fruit and vegetables in the diet. Although most people know that they are recommended to eat 5 portions of fruit and vegetables every day, less than 10% of the population achieve this target.

Many natural pigments currently used primarily for colouring purposes are phytochemicals which have been linked to good health (Guhr & Lachance, 1998; Pszczola, 1998; Mazza, 1998; Andreas M. papas, 1999, Overseal Foods Ltd, 1999). These are summarized as follows.

Curcumin

Historically turmeric (the source of the curcumin pigment) has been used as a medical treatment for its anti-inflammatory and antiseptic properties, as well as a spice. Curcumin is a potent antioxidant and protects against oxidative damage to cellular components. It has been found to inhibit the initiation, promotion and progression of cancers, enhance the activities of specific enzymes responsible for digestion, act as an antibacterial agent, promote liver detoxification and there are even reports of its anti-HIV properties.

Anthocyanins

The components of many red fruits such as grapes, blueberries, cherries and cranberries are thought to play a significant role in preventing or delaying the onset of many diseases. The phenolic compounds present include anthocyanins, phenolic acids, flavanols, tannins and resveratrol.

Much research has focused on these phytochemicals which are present in red wine and consequently in black grapeskins, in line with findings of the 'French Paradox' linking the red wine intake to a reduced incidence of heart disease and cancers.

The compounds present in red wine are known to be powerful antioxidants and have been identified as having a wide range of biochemical and pharmacological effects including anticarcinogenic, anti-inflammatory and antimicrobial, and will prevent both the LDL (low density lipoprotein) oxidation and the subsequent onset of cardiovascular disease.

There is certainly scope for developing ingredients based on natural anthocyanins with standardized levels of the beneficial compounds, for inclusion into a finished functional food product.

Carotenoids

Carotenoids are widespread in nature with more than 600 having been identified. The health benefits of carotenoids lie in two main areas:

- Antioxidant activity by protecting cells against oxidative damage, which is thought to lead to degenerative diseases such as atherosclerosis,

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cancer, arthritis and macular degeneration.

- Pro-vitamin A activity. β-Carotene and α-carotene have an pro-vitamin A activity and as such can be converted within the intestinal mucosa to vitamin A. Carotene colour formulations can therefore be used to contribute to any vitamin A claim that is made, as well as providing the colouring effect.

Much scientific research has been completed on the health benefits of carotenoids. A great deal of research has focused on β-carotene alone, but there is now increasing evidence that the carotenoids work synergistically and therefore an intake of mixed carotenoids is more beneficial, as this is how carotenoids would be taken from food sources, such as carrots. Mixed carotenoids from the fruit of the palm oil tree have a very similar composition to the carotenoids in the orange carrot. The health benefits of the carotenoids present in palm oil are shown in Table 6.

Lycopene

Lycopene, the natural pigment found in tomatoes may help in reducing the risk of several cancers such as prostrate and cervical cancer. Studies have indicated that lycopene may be more efficiently absorbed from processed tomato products such as ketchup and sauces than from raw tomatoes.

Lutein

The xanthophyll pigment Lutein has been recognized as an antioxidant. It is one of the two carotenoids found in the macular region of the eye and evidence suggests that lutein may protect against age related macular degeneration, a leading cause of blindness in people over the age of 65. Lutein based supplements are widely available in the USA based on this evidence. A diet rich in lutein is also thought to decrease the incidence of cataracts. There is also increasing evidence that lutein has anticancer properties.

Chlorophylls

Chlorophyll has been shown to have wound healing, antigenotoxic and antimutagenic properties. It has also been cited as a deodoriser to reduce body odour and bad breath. Certainly chlorophyll has received far less interest than carotenoids, but appear to have potential against environmental and dietary mutagens. Further studies will no doubt be done.

Increasingly supplements in the form of functional foods have been viewed as a way of addressing the dietary deficiencies mentioned above, that may contribute to many degenerative diseases. Functional foods are defined as those that give a health benefit in addition to any classical nutritional value. Food bases with the addition of phytochemicals can address this need and help to close the void between actual and required phytochemical consumption that is necessary for long term health.

At the beginning of the 21st century it is predicted that many colours will be used for both their nutritional value as well as colouring effect. One limiting factor is the current lack of regulations within the EU in this area, which need to be finalized so that phytochemicals can realise their full potential in the functional food arena.

Conclusions

Although many advances in the developments of food colours have been made over the last 25 years, particularly in terms of harmonized legislation and advances in processing and formulation technology, there is still room for future developments.

The overall colour market is forecast to grow in line with technological and sociological changes that will lead to an overall increase in processed foodstuffs. It is thought that the natural colour market will grow on a global scale at a greater rate than synthetic colours owing to a continued consumer pressure to 'go natural'.

Developments in artificial colours will continue to

Table 6 Identified health benefits of palm carotenoids

Carotenoid	Health benefit
α-Carotene	Thought to have inhibitory effect on the progression of certain types of cancers
β-Carotene	Works against free radical damage. A mixture of cis and trans β-carotene is thought to be more beneficial
Lycopene	Thought to protect against prostrate and cervical cancer

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focus on customized blends and technical support as well as further improved handling properties.

Significant developments in natural colours have occurred over the last 10 years and this is likely to continue in the area of stabilizing the currently permitted range of pigments by the development of the formulation and processing technology as well as the continued searches for 'untapped' sources of permitted pigments. Developments are only likely to cease when colours such as a heat and acid stable vegetarian natural red colour has been developed or alternatively a stable non pH dependant natural blue shade!

There is also further work to complete a full range of GM free colours to meet current consumer/retailer concerns, especially in the nature identical colour area.

The growing functional food ingredients market is likely to see natural pigments used for their health giving rather than their colouring properties. This is a very exiting area 'waiting to happen', which should be realized in the future.

Acknowledgments

In the preparation and writing of this paper we would like to thank the following contributors: Gareth Edwards of RHM Technology, Peter Comlin of Cerestar UK, Warner Jenkinson Europe, Hilton Davis (BF Goodrich), Pointing Ltd., Hoffman la Roche and BASF.

The chemical structures mentioned in this paper are available visually as downloadable files and can be reached at http://www.blackwell-science.com/products/journals/suppmat/ijfst/formulae.htm. The text of the paper is also available as a downloadable file at http://www.blackwell-science.com/ifs. Both are free to all readers.

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