Trends in Analytical Chemistry 85 (2016) 47–56

Contents lists available at ScienceDirect

Trends in Analytical Chemistry

journal homepage: www.elsevier.com/locate/trac

Methods for the analysis of Sunset Yellow FCF (E110) in food and beverage products- a review

Kobun Rovina [a], Pillai Perumal Prabakaran [b], Shafiquzzaman Siddiquee [a,*], Sharifudin Md Shaarani [b]

[a] Biotechnology Research Institute, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia
[b] Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia

ARTICLE INFO

Keywords:
Food dyes
Sunset Yellow FCF
Toxicology
Analytical methods
Electrochemical sensor

ABSTRACT

Food colorants are categorized into natural and synthetic dyes. One of the famous synthetic food dyes is Sunset Yellow FCF (E110) which belongs to the family of azo dyes and widely used in food industry. However, Sunset Yellow has positive and negative effects as well, by giving attractive physical appearance and consumer acceptance. At the same time, it can cause as attention deficit hyperactivity disorder (ADHD), is a group of behavioural symptoms that include inattentiveness, hyperactivity and impulsiveness, cancer and some other health effects with an excess consumption. Due to the arising of the health issues for mankind, researchers should give more priority to develop advance techniques for determination of Sunset Yellow in food and beverage products. The main aim of this review paper is critically discussed on the acceptable daily intake (ADI), toxicology, extraction methods, and analytical and electrochemical sensor methods for determination of Sunset Yellow.

Contents

* Corresponding author. Tel.: +60 88320000 ext. 8467; Fax: +60 88 320993.
E-mail address: shafiqpab@ums.edu.my (S. Siddiquee).

http://dx.doi.org/10.1016/j.trac.2016.05.009
0165-9936/

1. Introduction

Over the past centuries, food and beverage products are used different colors due to take several advantages of scientific and technological developments to maintain the nutritional and health-related. They are provided humans with numbers of compounds actively participating in various biological processes. Nowadays, color additives are commonly applied in variety of foods including dairy products, beverages, cereals, snack foods and ice creams to make them more attractive and appetitive. Among various type of food additives, food colorants are played an important role in foodstuff due to their physical appearance and consumer acceptance. Food colorants are categorized into natural and synthetic dyes. However, synthetic food dyes are widely used in food industry as compared to natural colorant because it is high in cost and instable during food processing as like as more stable in light, oxygen, pH, color uniformly, microbial contamination, strong tinting ability, and low cost. Synthetic color additives are organic pigments using artificial synthesis methods and generally made by coal tar from aniline dyes as raw material [1,2].

Synthetics food dyes are basically divided into two groups which are fat soluble and water soluble (Sunset Yellow FCF, Tartrazine, Brilliant Blue, Allura Red, and Amaranth etc). One of the most famous synthetic dyes is Sunset Yellow which belongs to azo food dyes group. Azo dyes are the largest group of synthetic dye which has azo (—N═N—) functional group or chromophore, so it can be found in synthetic dye together with aromatic ring structures [3,4]. Sunset Yellow has recognized as food additive by Joint FAO/WHO Expert Committee on Food Additive (JECFA) and EU Scientific Committee for Food (SCF) in 1982 and 1984, respectively [5]. Recently, several synthetic dyes have been reported highly resistance against degradation and posed slight toxicity to human and animal health. Excess consumption of these compounds may lead to several serious health problems including allergy and asthmatic reaction, DNA damage, hepatocellular damage, renal failure, attention deficit hyperactivity disorder (ADHD), potential immunotoxicity, and reproductive toxicity. In China, Sunset Yellow is severely used as additives in certain food products due to some toxicity cases. In 2013, Ministry of Health Malaysia has found a case on contaminants of Sunset Yellow on chicken meat products which resemble chicken to deceive consumers [4,6].

For the assurance of consumer health, it is important to control Sunset Yellow in foodstuff by developing a simple, economic and rapid analytical method for food safety and human health. In recent years, several analytical methods have been developed for determination of Sunset Yellow such as high performance liquid chromatography (HPLC), thin layer chromatography, visible spectrophotometry, fluorescence emission spectrometry and so on. Unfortunately, there has some limitation of these methods including costly equipment, time consuming as well as need of special trained operators. Recently, the advanced electrochemical sensor methods have led more attention in practical application due to high sensitivity, short analysis time, good handling convenience and low cost [7]. Therefore, this review paper is critically discussed on the Sunset Yellow detection techniques including analytical and electrochemical sensor with different food matrices and also particularized on the extraction methods, acceptable daily intake (ADI) and toxicology of Sunset Yellow.

2. Sunset Yellow FCF

2.1. Structure and application

Sunset Yellow ($C_{16}H_{10}N_2Na_2O_7S_2$, $M_w = 452.38$, Fig. 1), one of the azo dyes which called evening yellow and edible yellow No. 3. It is one of the synthetic pigments that added in foods (GB2760-2011), and widely used in pharmaceuticals and cosmetics [8]. Azo dyes are the largest group of synthetic colorants (60–70%) and used to color a large number of different substrates including synthetic and natural textile fibers, plastics, leather, paper, mineral oils, waxes, foodstuffs and some cosmetics [9]. Sunset Yellow consisted of 2-hydroxyl-(4-sulphonatophenylazo) naphthalene-6-sulphonate and subsidiary coloring matters together with sodium chloride and/or sodium sulphate as the major uncolored components. Besides, Sunset Yellow can be synthesized by diazotizing 4-aminobenzenesulphonic acid by the presence of sodium nitrite [5]. It is also able to form NH-hydrazone or -OH hydroxyl azo by the presence of two sulfonate groups which lead to high soluble in aqueous solution [10]. Furthermore, Sunset Yellow is normally applied in food and pharmaceuticals to impart orange or red color. It is usually used in the production of swiss roll, soft drinks, jellies custard powders, sodas, juices, candies, ice creams and jam [2,11,12].

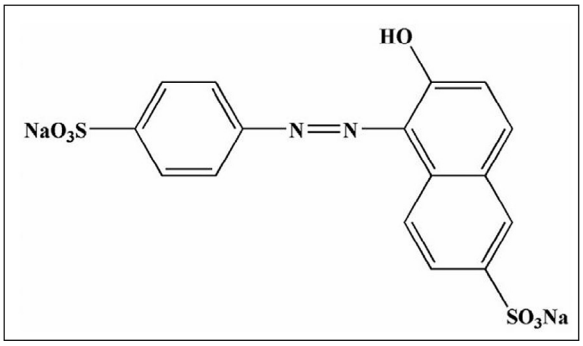

Fig. 1. Chemical structure formula of Sunset Yellow FCF.

2.2. Acceptable daily intake (ADI)

Acceptable Daily Intake (ADI) of food dyes defined as an estimation of the upper threshold of the amount of food additives and expressed on body weight basis, which can be ingested in daily over a lifetime without any significant risk. The ADI value has obtained by multiplying the average amount of the food coloring consumed by the average levels of color additives in foods and then dividing the result by the average body weight for each group [13]. Besides, WHO has standardized the maximum permissible limitation of Sunset Yellow is up to 200 mg/kg. Meanwhile, EU and Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 1982 and EU Scientific Committee for Food (SCF) in 1984 have allowed the suitable ADI of Sunset Yellow from 0 to 2.5 mg/kg/bw/day [14]. According to Malaysian Food Act 1903 and Food Regulation 1985, all permitted food additives used in the foods have to be listed in ingredient label.

However, government of India has allowed the maximum permissible limit of 100 or 200 ppm (rule 30) and the food colorant must be free from any harmful impurities (rule 31) while individually added or in the mixture form. This value relatively has lower as compared to ADI set by JECFA and SCF due to Indian community's food consumption habit which is preferable high in food colorants during festive seasons [15]. Dixit et al. [16] have reported Sunset Yellow is a leading food dye in Uttar Pradesh, India. In Brazil, ADI level is similar to EFSA for Sunset Yellow in solid juice powder, solid jelly powder and soft drinks [17]. In 1965, it has legally permitted synthetic food colorant under the 'Pakistan Pure Food Rules' [18]. While US FDA sets ADI for children below 30 kg to 113 mg/p/d and for US population (60 kg person) to 225 mg/p/d. In similar study conducted by Lok et al. [13] and revealed that Sunset Yellow has higher in soft drinks and desserts as compared to other

synthetic colors in Hong Kong. Sunset Yellow was banned in Norway and Finland [19].

3. Toxicology of Sunset Yellow FCF(E110)

Synthetic dyes are common ingredients which are added in foods products. Excess consumption of synthetic dyes may adversely affect human health such as allergies, respiratory problems, thyroid tumors, chromosomal damage, urticaria, hyperactivity, abdominal pain, and many others [20]. Synthetic dyes are commonly combined with several harmful compounds which including lead, mercury, arsenic, and benzidine that can effects human health especially body functions. Combination with the compound may result in urticaria, rhinitis, nasal congestion, bronchoconstriction, anaphylactoid reaction, eosinophilotactic response, purpura (bruises), allergies, kidney tumors, chromosomal damage, abdominal pain, vomiting, indigestion and distaste for food. Additionally, artificial food dyes are able to assist the growth of cancer due to the prolonged use and sustaining the artificial colorant in the human body. Attention Deficit Hyperactivity Disorder (ADHD) has reported an approximately 2.5 million children in the United States under medication in 2003 [21]. Bateman et al. [22] have clearly identified by their parents that there are significantly changes in the behavior of a hyperactive child aged within three years. Nettis et al. [23] have found intolerance of child when used 5 mg of synthetic dyes which react to double-blind, edema face, urticaria, abdominal pain and slight hypotension. Two synthetic dyes have increased with sodium benzoate in the diet which can lead to increase hyperactivity in children less than three years and eight to nine years from the general population [24]. Besides, Mikkelsen et al. [25] have reported that combination of Allura Red AC, Amaranth, Sunset Yellow FCF, Ponceau 4R, and Tartrazine dyes can cause chronic urticaria or angioedema to the patients.

Sunset Yellow particularly is one of the synthetic dyes which lead to asthma, immunosuppression, eczema and anxiety migraines if excessively consumed. Sarıkaya et al. [26] have revealed that a synthetic dye is potential suspect in causing cancer. Blue 1, Blue 2, Red 40, Yellow 5 and Yellow 6 (Sunset yellow) are the type of food dyes that are commonly associated with dyes that can cause cancer to human being. These dyes are usually found in Kellogg, hot fudge sundae, tart, soft drinks and candies [27–29]. The formation of cancer cell has occurred when chemical compounds (e.g., heavy metal) bound to the synthetic dyes and caused degradation of azo bond cleavage (N═N) that lead to convert into a free form in the colon [30–33].

Sunset Yellow has suppressed behavior as well as increase the percentage of mitotic abnormalities consistent in human cell. The toxicity and carcinogenicity of Sunset Yellow in mammalian systems might be caused by interaction with receptor molecules intact cytosolic or through the formation of free radicals and arlyamines azoreduction. Reactive oxygen species (ROS) such as hydroxy radical (OH), superoxide anion radicals (O_2) and hydrogen peroxide (H_2O_2), will be produced during normal metabolism by consequence of an abnormal response to stress [34–36]. Chen [37] has stated that azo dyes can be reduced by microsomal and cytosolic reductase in the liver and extra hepatic tissues which played a vital role in the metabolism process. Bras et al. [38] have reported the same issue of azo dyes metabolism by anaerobic microorganisms in the human gut, which resulted carcinogens of aromatic amine.

Food Additives and Nutrient Sources (FANS) have reassessed the safety of Sunset Yellow due to some aromatic amines associated with a genotoxic or carcinogenic. Sunset Yellow has absorbed from the gastrointestinal tract and follow-on slums through faeces. It could be a component of contributor for growth of cholestasis which in combination with other elements, could pre-dispose the development of primary biliary cirrhosis (PBC) [39]. Yadav et al. [40] have reported the Sunset Yellow can be suppressed mitogen induced proliferation of splenocytes and MLR reaction. The analysis of immunophenotypic Sunset Yellow has revealed that relatively CD3e/CD4/CD8 in T cells and CD19 on B cells with the suppression of T-cell line and B cells that altered expression of the surface receptors. It is reduced the disclosure IL2, IL4, IL6, IL-17, IFN-γ and TNF-α cytokine. Finally, it is indicated that non-cytotoxic dose of Sunset Yellow may have the continuous effect of immunomodulatory.

Sunset Yellow can diminish the weight of the thymus gland and reduced the percentage of monocytes [19]. Meanwhile, Sharma et al. [41] have reported that excess consumption of Sunset Yellow effects on the body weight, hematology and serology of albino mice as well as infusing these artificial dyes may contain the same effects on the human health. Tsuboya et al. [42] and Macioszek & Kononowicz [43] have delineated that the azo dyes are able to induce the DNA damage *in vivo* and *in vitro*. A single or repeated oral treatment with Sunset Yellow has generated chromosomal aberrations that are very much significant in bone marrow cells and spermatocytes [34,44]. Determination of Sunset Yellow in a rapid, sensitive and simple manner is quite important for human health and food safety.

4. Extraction of Sunset Yellow FCF (E110) from food matrices

There are various foodstuffs in local market containing azo dyes especially Sunset Yellow as food dyes. Pretreatment of the food samples are necessary before proceed for the detection of specific synthetic colors. Basically, there are no standard methods for extractions in laboratories have been reported previously. However, Thompson and Trenerry [45] and Wu et al. [46] have mentioned that most extraction methods have followed a common path involving the release of desired analytes from their matrices then removing by extraneous matter and a suitable extraction method. Several extractions methods have been used to analyze the azo dyes including Sunset Yellow in different food matrices.

4.1. Membrane filtration

A membrane is a thin layer of semi-permeable substance that separated the substances when an external driving force has applied across the membrane. For azo dyes in beverages, the most common extraction procedure has applied by one-step extraction with membrane filter using water as diluents due to easy, simple, efficient, and robust sample preparation technique. The foodstuff samples can be directly filtered or diluted followed by filtration, prior to HPLC analysis. The selection of filters should emphasis the membrane type and pore size, filter dimension, properties of target analytes and need of instrument analysis [27,47]. Minioti et al. [27] and Gosetti et al. [47] have used membrane filtration extraction technique to determine several synthetics dyes including Sunset Yellow.

4.2. Solid-phase extraction (SPE)

Solid phase extraction (SPE) technique is widely used for determination of azo dyes due to rapid and simple preparation procedure. SPE method is able to extract food dyes in large volume, less contamination and resulting high recoveries value. Normally, there are some typical sorbent for SPE such as C_{18} column, amino-functionalized low degrees of cross-linking magnetic polymer (NH_2-LDC-MP) [48], polyamide, gel permeation chromatography (GPC) [49,50] and styrene-divinylbenzene polymer [51] that has good retention towards Sunset Yellow. Different organic solvents are used in the analysis of azo dyes due to difficulty choosing of the suitable solvent. The structure of analytical matrix and its components have played important role for choosing an appropriate solvent for extraction. For example, methanol, acetic acid, ethanol, acetone, ethyl acetate and tetra-n-butyl ammonium phosphate are more

appropriate for the extraction of azo dyes. Chen et al. [48] have reported the use of NH_2-LDC-MP as a solvent in SPE under magnetic field able to enhance the extraction recoveries of seven synthetic food dyes using pure water (pH 9.0) as an extraction solvent. Tang et al. [50] have studied the extraction of sixteen artificial dyes in complex hotpot condiment with high oil content. Based on their results, the combination of methanol, acetone (1:1, v/v) and 2 mol L^{-1} carbamide solution containing 5% ammonia in methanol have shown good extraction efficiency when purified by a GPC column. Harp et al. [52] have carried out SPE method to extract seventeen food colorants in forty-seven food products including Sunset Yellow. González et al. [53] have determined natural and synthetic colorants in lyophilized foods using an automatic SPE system using ammonia, methanol mixture as eluents and RP-C_{18} cotton as stationary phase.

4.3. Liquid-liquid extraction (LLE)

Liquid-liquid extraction (solvent extraction) is a technique for compounds separation based on their relative solubility with two different immiscible liquids (organic phase and water). It is an extraction of a substance from one liquid into another liquid phase. Several solvents are widely used for extraction of azo dyes from food products such as water, ethanol, methanol, isopropyl alcohol, ammoniacal ethanol, ethyl acetate, ammonia, cyclohexane and tetra-n-butyl ammonium phosphate. Various LLE methods have been used for the extraction of Sunset Yellow. For example, Zou et al. [54] have found that the trimixture of ethanol, ammonia and water (80:1:19, v/v/v) are showed excellent extraction recoveries for seven dyes in animal feed and meat samples. They are used ethanol-ammonia-water (80:1:19, V/V/V) solution as extract solution, which can extract Sunset Yellow while reducing interference from the sample matrices. Furthermore, Harp et al. [55] have identified seven certified food colors in forty-four food products using ammonium hydroxide and methanol as extraction solvents. Reza et al. [56] have extracted the food dyes by using salting-out assisted liquid-liquid extraction (SALLE) method. Coelho et al. [57] have used Polyester-type Polyurethane (PU) foam to extract Sunset Yellow, Brilliant Blue and Tartazaine from a solution containing different food matrices. Khanavi et al. [58] have developed a green extraction procedure by using non-organic solvents such as ammonia (0.25%, v/v) and water for the extraction of dyes from food products and medicines. They are used eco-friendly extraction solvents due to their low toxicity profile.

4.4. Others extraction

Others extraction methods have been used such as microwave-assisted extraction (MAE) and ultrasound-assisted extraction (UAE) which are more appropriate eco-friendly methods. However, this is a conventional method with characterize the organic solvents by using high volumes of solvents and time consuming. The result often showed low recoveries value, less selectivity and precision. There are few literatures have been reported by using this method. Shen et al. [59] have developed a method of extraction using two phase solvent (methanol and acetone) and UAE which has resulted in improved extraction recovery of both hydrophilic and hydrophobic pigments. Besides, Sun et al. [60] have studied the extraction of twenty-one synthetic colorants in meat by MAE using methanol-acetic acid (95:5, v/v) as a solvent. In contrast, there are few methods available without required extraction procedures before analysis the Sunset Yellow [61].

5. Analytical techniques for determination of Sunset Yellow FCF(E110)

Analytical detection techniques are developed for monitoring the presence of synthetic dyes products which in high consumption like beverages and candies [62]. Normally, Sunset Yellow FCF (E110), Tartrazine (E102), Amarnath (E123) and Brilliant Blue (E133) dyes are widely used in food and beverage products [8]. Up to now, different analytical methods have been established such as chromatography, enzyme-linked immunosorbent assay (ELISA), spectrophotometry, capillary electrophoresis and surface-enhanced raman scattering for the determination of Sunset Yellow.

5.1. Chromatography

Chromatography is one the effective and appropriate method for determination of synthetic dyes in food and drink samples. These techniques can be applied in different types of water-soluble dyes for separation of components in food matrices. The separation will be run through the stationary phase of dye sample and mobile phase of water based on the adsorption or restrictions solute between two phases of non-soluble mixture [63,64]. Generally, there are two types of chromatography techniques are commonly used for determination of Sunset Yellow; thin layer chromatography (TLC) and high performance liquid chromatography (HPLC).

5.1.1. Thin layer chromatography (TLC)

Thin layer chromatography (TLC) is one of the simple chromatographic due to the low cost apparatus. TLC is commonly used for separation and determination at the level of dyes in food products and beverages. It is a phase entrapment technique where stationary phase has the glass plate that coated with a layer of silica gel and the mobile phase act as an organic solvent. Organic solvents are the most popular in chromatographic techniques. Unfortunately, they have intensive disagreeable smell and cancerogenic activity. Thus, water-methanol solution of β-cyclodextrine has proposed as mobile phase and polyamide sorbent as stationary phase to replace organic solvents [65]. Soponar et al. [66] have developed a HP-TLC method combined with image processing of scanned chromatograms. The LOD were found within the range of 5.21–9.34 ng/spot, and recoveries values between 96.39–102.76%. These results showed the regression approach provides rigorous and realistic detection and quantification limits and as a consequence can be routinely applied to other analytical systems. Tang et al. [67] have established a polyamide thin-layer chromatographic (TLC) method in combination with on-plate solid-phase extraction and backlight-assisted for determination of five commonly used synthetic colorants in foods. The limits of detection for Sunset Yellow found 4.12 ng. The proposed technique has rapid, low-cost and sensitive, providing a green limit test method for five colorants in beverage and food products.

5.1.2. High performance liquid chromatography (HPLC)

High performance liquid chromatography (HPLC) method is commonly used to determine the presence of synthetic food dyes because it can offer good repeatability and acceptable sensitivity with the traditional UV-vis detection. However, most HPLC methods have established for colorant analysis suffer from limited separation ability, and are time consuming especially when the simultaneous determination of a broad range of food colorants. Basically, HPLC method is used through the chromatographic peak area and calibration graph peak area that is plotted against the concentration of dye to calculate uniformity [68]. This method usually combined with others such as HPLC coupled with diode array detector (HPLC-DAD) [69–71] and HPLC-DAD with ultrasound assisted solvent extraction [59], HPLC with ultraviolet detector method [46], HPLC-DAD and tandem mass spectrometry [54], reverse phase HPLC and poly(N-isopropylacrylamide-co-N,N″-methylene bicrylamide) monolithic column with built-alumina nanoparticles/microextraction HPLC [72].

Sha et al. [28] have developed a rapid and effective method for the simultaneous determination of five synthetic food colorants in

Table 1
Summary of analytical techniques for determination of Sunset Yellow

Spectroscopic technique	LOD	Reference
Polyamide TLC	4.2 ng/mL	[67]
HPLC with UV detection	0.051–0.074 ng/mL	[28]
Ultrasound assisted solvent extraction and HPLC	10 ng/mL	[59]
TLC and ion-pair HPLC	0.024 μg/mL	[73]
Poly (N – isopropylacrylamide - co – N, N′ - methylene bisacrylamide) with HPLC	9.5 ng/mL	[72]
HPLC with ultraviolet detection	0.015 ng/mL	[46]
HPLC-DAD and HPLC-MS/MS	74.81 and 2.18 ng/mL	[54]
HPLC- diode array detector	0.1 mg/L	[71]
HPLC- diode array detector	100 μg/L	[70]
HPLC	0.027 μg/mL	[69]
HPLC	50 ppb	[17]
HPLC	143 ppb	[74]
HP-TLC	5.21 ng/spot	[66]
UV-vis spectrometry	0.085 ppm	[75]
Spectrophotometry	0.6 μg/mL	[76]
UV-vis spectrophotometry	0.23 mg/L	[1]
Spectrophotometry	5.2 μg/L	[77]
UV-vis spectrometric	0.25 mg/L	[56]
UV-vis spectrophotometer with diode array detector	0.23 mg/L	[20]
Spectrophotometry	16.67 ng/mL	[78]
Kinetic spectrophotometry	0.04–0.50 mg/L	[79]
Fluorescence spectroscopy	1.07–1.11 μg/mL	[80]
Photoacoustic spectrophotometry	0.028 mg/L	[57]
HLA/GO	0.52 μg/mL	[8]

food samples. They are used 1-alkyl-3-methylimidazolium bromide as the extraction reagent with above 95% efficiency for the five colorants. The method has successfully applied in real food samples with LOD range from 0.051–0.074 ng/mL. Wu et al. [46] have addressed a rapid shaking-based method of ionic liquid dispersive liquid phase microextraction for the determination of six synthetic food colorants including Sunset Yellow in soft drinks, sugar and gelatine. Under optimum conditions, the method showed high sensitivity with LOD of 0.015–0.32 ng/mL and spiked recoveries from 95.8 to 104.5%. Zou et al. [54] have proposed efficient techniques for determination of synthetic sulfonate dyes in animal feed and meat using HPLC-DAD and tandem mass spectrometry (HPLC-MS/MS). The LOD was found in the range of 0.02–21.83 ng/mL with recoveries study in animal feed and chicken meat between 71–97%. The others chromatography techniques are summarized in Table 1.

5.2. Enzyme-linked immunosorbent assay (ELISA)

Enzyme-linked immunosorbent assay (ELISA) technique is mostly used for the detection of various additives in real systems because of their rapidity, mobility, high sensitivity and low detection limit [81,82]. Xing et al. [4] have established a novel technique for determination of Sunset Yellow by using a polyclonal antibody-based indirect competitive enzyme assay immune absorbance concentrated (ic-ELISA) as shown in Fig. 2. They are used dilution extraction method reducing the interferences in the food matrices with some modification [83] and LOD found of 25 ng/mL. They also mentioned that there is no research about the production of antibodies against Sunset Yellow or development of ELISA for its determination in real samples including beverage, dried beancurd, braised pork and serum.

5.3. Spectrophotometry

The spectrophotometry techniques are mainly applied for identification and quantification of synthetic food dyes such as UV-vis spectrophotometry [1,56,75], UV-vis spectrophotometer with diode array detector [20], kinetic spectrophotometry [79], fluorescence spectroscopy [80], photoacoustic spectrophotometry [57], and HLA/GO [8]. UV-vis spectrophotometry method for the analysis of the synthetic dyes in food and beverages products by dissolving sample material into distilled water. The sample solution has stored in cuvette and scanned at a wavelength of 300–800 nm. The maximum wavelength of spectrum has detected different types of color present in samples.

Reza et al. [56] have addressed a simple technique for determination of Sunset Yellow in wastewater and food samples. They are extracted the color by salting-out assisted liquid-liquid extraction (SALLE). Under optimum conditions, calibration plot is found to be linear in the range of 0.4–15.0 mg/L, with coefficient of determinations more than 0.996. The LOD found of 0.07 mg/L, with LOQ is 0.25 mg/L. Goicoechea and Olivieri [84] have developed a calibration methods based on HLA applied in chemical analysis with satisfactory results. Similarly, Al-Degs [8] has used hybrid linear analysis (HLA/GO) method to quantified azo dyes against standard HPLC method for validation. Dinc et al. [85] have addressed double divisor-ratio spectra derivative, classical least-squares and principal component regression methods to analyze the synthetic dyes in soft drink. The linear was found ranges between 2–8 μg/mL of Sunset Yellow in 0.1 M HCl with low detection limit.

Sorouraddin and Saadati [86] have described a simple and low cost reflectometer for resolving binary and ternary mixtures of some food dyes. This device used an array as light source and combined with a light dependent resistor to become a sensor. Based on the observation, it is indicated that this method is more accurate, precise, reproducible, and could be utilized directly to the routine analysis of the food samples. Coelho et al. [57] have conducted photoacoustic spectroscopy (PAS) technique and compared with first derivative spectrophotometry (FDS) to identify the specific food colorant in foodstuff. Based on the findings, PAS method has showed greater sensitivity, with LOD of 0.028 mg/L. Thus, PAS technique can be applied for determination of the selected dyes in commercial food products because it reduces the number of analysis steps, less chemical waste, a minimal sample amount is needed, and non-destructive [87]. A typical PAS assembly is represented in Fig. 3 which consists of a light source, a monochromator, a light modulator, a photoacoustic cell with a condenser microphone, a lock-in amplifier and a data acquisition system.

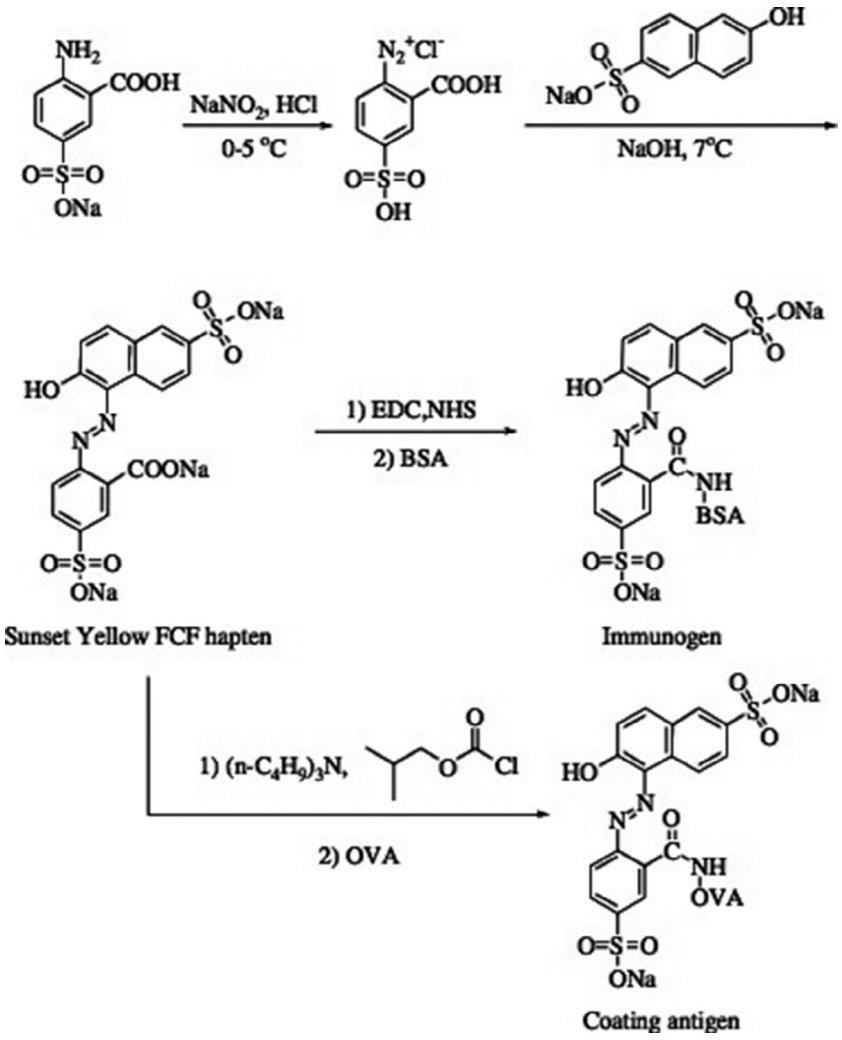

Fig. 2. Schematic synthesis of Sunset yellow hapten, immunogen and coating antigen [4].

5.4. Capillary electrophoresis (CE)

Capillary electrophoresis (CE) has been pointed out as a very satisfactory technique for the simultaneous determination of different compounds from synthetic dyes. This method is particularly suited to achieve highly efficient separations of food dyes. CE are widely used for the analysis of food colorants due to its many advantages, such as high column efficiency, short analysis time and minimal amounts of samples. Unfortunately, the limitation of CE are limited sensitivity and selectivity and severe matrix interferences, which greatly restrain its further use in real sample analysis.

Liu et al. [88] have used CE technique for determination of food colorants in beverage samples by using diamino moiety functionalized silica nanoparticles (dASNPs) as both adsorbents in dispersive solid-phase microextraction (dSPME) and pseudostationary phases (PSPs). Linearity with correlation coefficients is 0.9932 and LOD between 0.030 to 0.36 mg/L. This is the first reported to use NPs both as extractants in dSPME and pseudostationary phases in CE for the analytical purpose. An aqueous CE method with diode array detection enabled the determination of eight food colorants in milk beverages with LOD of 0.5 μg/mL. The combination of the simple SPE pretreatment and the fast separation method of CE is successfully determined synthetic dyes without matrix interference the content of those colorant additives in commercial milk beverages [89]. Perez-Urquiza and Beltran [90] have developed a rapid method based on capillary zone electrophoresis coupled with photodiode-array to determine the azo dyes dyes in foodstuffs. Separation procedure is used a Bare CElect-FS75 CE column and showed LOD and LOQ are 1.7 ppm and 5.5 ppm, respectively.

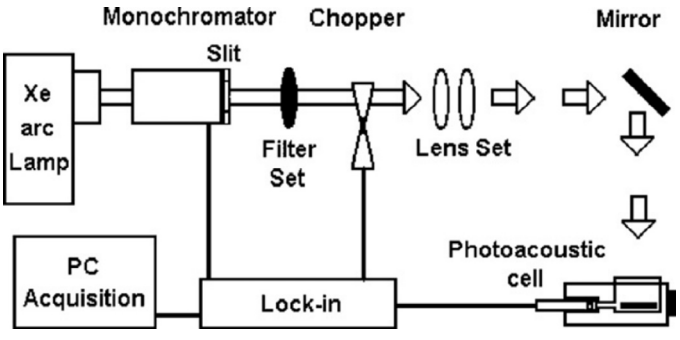

Fig. 3. Experimental design for PAS [57].

5.5. Surface-enhanced raman scattering (SERS)

Surface-enhanced raman scattering (SERS) has developed rapidly and become a powerful method, subsequently the enhanced raman

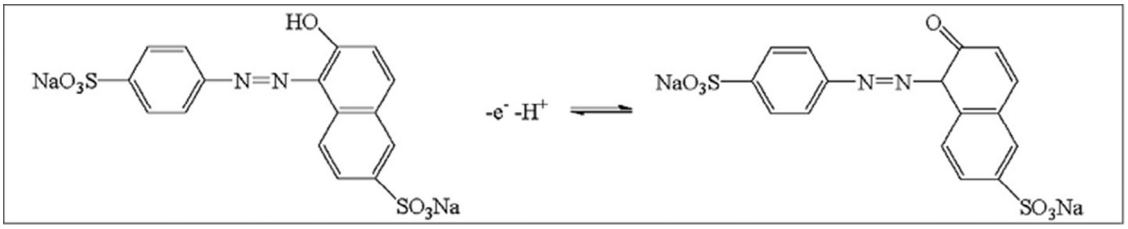

Fig. 4. Redox mechanism for the electrochemical process of Sunset yellow [109].

spectrum of pyridine has observed and confirmed at a silver electrode [91–93]. Xie et al. [94] have studied SERS substrate made up of SiO_2@Au nanoshells and showed an excellent enrichment effect for determination of Sunset Yellow with LOD of 1 ppm. Under optimal condition, it has proved possible to distinguish each colorant by its characteristic peaks in the SERS spectra of a mixture of the two colorants. Roosta et al. [95] have investigated the efficiency of zinc hydroxide nanoparticle loaded on activated carbon ($Zn(OH)_2$-NP-AC) in determination of Sunset Yellow from aqueous solutions using ultrasonic-assisted adsorption method. The method successfully applied for the determination of Sunset Yellow (>97%) in short time (5 min) with high adsorption capacity (83–114 mg g^{-1}).

6. Electrochemical sensor for determination of Sunset Yellow FCF (E110)

Advance methods are needed to develop for determination of Sunset Yellow due to high sensitivity, selectivity, rapidity, simplicity and cost effectiveness. Electrochemical technique is mostly used in advance detection technique for artificial food dyes since past decade. Different types of electrode modification for electrochemical methods have developed for the determination of Sunset Yellow because they possessed high sensitivity, short analysis time, good handling convenience and low cost. Inappropriate choosing of electrode may detect the food dyes but the sensitivity or detection limit might be lower than the appropriate electrode. The common electrode generally used in electrochemical technique is glassy carbon electrode (GCE), however, gold electrode (AuE), platinum electrode (PtE) and many more. Different electrodes may give different results which are much depending on the redox reaction property of analyte [7,96–98].

Songyang et al. [99] have used montmorillonite calcium (MMT-Ca) that functionalized with cetyltrimethylammonium bromide (CTAB) via cationic exchange effect become CTAB/MMT-Ca. The developed method showed highly-sensitive, rapid and simple for the determination of Sunset Yellow. The linear range was from 2.5 to 200 nM, and the detection limit is low as 0.71 nM after 1 min accumulation. Majidi et al. [100] have developed an electrochemical method based on carbon-ceramic electrode modified with 1-LYL-3-methyl imidazolium ionic liquids tetraflouroborate. The proposed technique showed linear response in concentration range of 1×10^{-7}–1.5×10^{-5} M, with LOD of 7.3×10^{-8} M. The recovery value ranged was found between 95.7–105%. Chao and Ma [101] have developed poly (L-phenyl-alanine) modified glassy carbon electrode (EULA/GCE) to detect Sunset Yellow and Tartrazine in food products. In the optimum peak current, Sunset Yellow has showed a linear relationship with the concentration range of 181 to 6333 mg/L with the LOD of 18.1 mg/L. Yu et al. [102] have used a hexadecyltrimetylammonium bromide (CTAB) functionalized graphene combine with platinum nanoparticles (CTAB-GR-Pt) composite through one step hydrothermal modified GCE. The linear detection range was 0.08–10 μM, and LOD was found of 4.2 nM.

Asadpour-Zeynali and Mollarasouli [75] have applied bismuth film modified GCE by using differential voltammetry method for determination of two azo dyes. The linear range of concentration has found of 5×10^{-5} M with detection limit of 4.52 μg/mL. Wang et al. [103] have applied polypyrrole (ppy) decorated oxidized single-walled carbon nanotubes (SCNT-COOH) electrode with LOD up to 7.0×10^{-10} M and acceptable recovery value was obtained. Similarly, Zhao et al. [96] have studied an imprinted ionic liquid polymer-ionic liquid functionalized graphene composite film coated GCE (MIP-rGO-IL/GCE) which is water-compatible electrode for detection of synthetic dyes. The interaction occurs through π-π, hydrogen-bonding and electrostatic interaction with peak current which is linear concentration ranging of 1.4–16.0 μM with LOD of 4.0 Nm.

Chen et al. [97] have studied alumina microfibers with hole structure to build a high sensitivity platform. The linear range is from 0.5 to 100 nM with a detection limit of 72.4 ng/L, after the build-up for 2 minutes. Li et al. [104] have successfully synthesized and modified to the GCE surface based on β-cyclodextrin/ionic liquid/gold nanoparticles functionalized magnetic graphene oxide to construct imprinted electrochemical sensor for detection of Sunset Yellow. Under optimal conditions, the sensor showed a fast re-binding dynamics, with a wide linear range from 5.0×10^{-9} to 2.0×10^{-6} mol/L and detection limit was found of 2.0×10^{-9} mol/L. Ye et al. [29] have used β-cyclodextrin coated with poly(diallyldimethylammoniuchloride)-graphene composite film (β-CD-DDA-Gr) for simultaneous detection of Sunset Yellow. The anodic peak currents showed an excellent result in the linear range of 5.0×10^{-8}–2.0×10^{-5} mol/L with trace limit of detection is 1.25×10^{-8} mol/L. Gan et al. [105] have developed electrochemical method based on graphene and mesoporous TiO_2 carbon paste electrodes with limit of detection of 6.0 nM and recovery range between 96.15–102.1%.

Qiu et al. [106] have designed graphene oxide and the excellent electronic and antifouling properties of multi-walled carbon nanotubes for determination of Sunset Yellow and Tartrazine. Under optimum conditions, the enhanced anodic peak currents represented the excellent analytical performance of simultaneous detection in the range of 0.09–8.0 μM, with a low limit of detection of 0.025 μM. Similarly, Majidi et al. [107] have used multiwalled ionic liquid carbon nanotubes nanocomposite for modification carbon-ceramic electrode. The linear range of concentrations is from 4×10^{-7} to 1.1×10^{-4} M, with detection limit of 0.045 mg/L and recovery range between 94.4–106%. Ghoreishi et al. [108] have modified carbon paste electrodes with gold nanoparticles. The modified electrode showed linear range of concentration between 1.0×10^{-7} to 2.0×10^{-6} $molL^{-1}$ with LOD is 3.0×10^{-8} mol/L and recovery falls in range of 95.0–104.0%. Furthermore, Gan et al. [109] have successfully designed a graphene layer-wrapped phosphotungstic acid (PTA) hybrid on the surface of GCE which functionize as an electron transfer mediator. The mechanism is shown in Fig. 4. The proposed method found linear ranges from 9–927 mg/L, with LOD of 0.5 ug/L. Therefore, this study has provided several evidences for development of portable sensors for food additives.

Gómez et al. [110] have explored a hanging mercury drop electrode with the existence of cetylpyridinium bromide (CPB) for detection of Sunset Yellow in gelatine and powdered soft drink. The

Table 2
Electrochemical techniques for determination of Sunset yellow in food products

Methods	Electrode	LOD	References
Cyclic voltammetry and electrochemical impedance spectroscopy	GCE modified with β-cyclodextrin/ionic liquid/gold nanoparticles	2.0×10^{-9} mol L^{-1}	[104]
Cyclic voltammetry and and linear sweep voltammograms	GCE modified with graphene oxide and multi-walled carbon nanotubes	0.025 μM	[106]
Cyclic voltammetry	GCE modified with 1-LYL-3-methyl imidazolium	7.3×10^{-8} M	[100]
Differential pulse voltammetry	Carbon paste modified with CTAB/MMT-Ca	0.71 nM	[99]
Cyclic voltammetry	EULA/GCE	18.1 mg/L	[101]
Cyclic Voltammetry and differential pulse voltammetry	CTAB-GR-Pt	4.2 nmol/L.	[102]
Net analyte signal standard addition method	BFE	4.52 μg/mL	[112]
Cyclic voltammetry and differential pulse voltammetry	Polypyrrole (ppy) decorated oxidized single-walled carbon nanotubes (SCNT-COOH)	7.0×10^{-10} M	[103]
Differential voltammetry	MIP-rGO-IL/GCE	4 nM	[96]
Cyclic voltammetry and differential pulse voltammetry	Alumina microfibers-modified CPE	0.16 nM	[97]
Cyclic voltammetry and differential pulse voltammetry	B-CD-PDDA/GCE	1.25×10^{-8} mol/L	[29]
Cyclic voltammetry	Gr-TiO2/CPE	6.0 nM	[105]
Differential pulse voltammetry	MWCNTs-IL modified electrode	0.045 mg/L	[107]
Differential pulse voltammetry	Gold nanoparticles CPE	3.0×10^{-8} mol/L	[108]
Cyclic voltammetry and differential pulse voltammetry	GN-PTA film modifies GCE	0.5 ug/L	[109]
Adsorptive stripping voltammetry	Hanging mercury drop electrode	1.6 ug/L	[110]
Cyclic voltammetry	Imprinted polypyrrole-GCE	N/AN/A	[11]
Differential pulse voltammetry	Boron-doped diamond electrode	63 nM	[7]
Multiple pulse amperometric-flow injection analysis	Boron-doped diamond electrode	2.5×10^{3} nM	[111]
Differential pulse voltammetry	MWCNT/GCE	22 nM	[113]
Differential pulse voltammetry	Platinum wire-coated electrode Graphene-PTA	316 nM	[114]

detection limit is obtained of 1.6 ug/L. Another advance method has developed by Medeiros et al. [7] which is a simple, low-cost and rapid method based on simultaneous voltammetric determination of two pairs synthetic food dyes by using DPV with cathodically pretreated boron-doped diamond (BDD) electrode. The recovery rate has found from 90.8–111%, with detection limit of 63 nM. Medeiros et al. [111] have developed for simultaneous determination of two pairs of food dyes with a single-line flow injection system and multiple pulse amperometric detection using a BDD electrode, with LOD found of 2.5×10^3 nM. The recent electrochemical techniques for determination of Sunset Yellow are summarized in Table 2.

7. Conclusion

Food colours are food additives which are added to foods mainly for the following reasons:

i) to make up for colour losses following exposure to light, air, moisture and varying temperature;
ii) to enhance naturally occurring colours appearance, its taste, and nutritional value

The use of food dyes are associated with allergies, food intolerance, cancer, multiple sclerosis, attention deficit hyperactivity disorder (ADHD), brain damage, nausea, and cardiac disease. High consumption of Sunset Yellow can cause several effects such as cancer, asthma, ADHD and hypersensitivity. Growing trend on healthy food among public attract attention on food safety and quality which can provide great interest to food industry and government bodies for determination of dyes in foods qualitatively and quantitatively. In this review highlighted with several analytical extraction methods including leaching and supercritical fluid extraction, solvent extraction, enzymatic digestion, membrane filtration and solid phase extraction techniques, and also determined of Sunset Yellow based on analytical and advanced techniques. Most of these methods are actual complicated pre-concentration, time-consuming steps and high-cost instruments. We recommend developing a rapid, sensitive and reliable method that can able to carry out safety evaluations of Sunset Yellow colour before can be authorised for use in products in marketing. Another recommendation to the Government passes a law refusing permission for the food industries to add unauthorized toxic agents into our daily foods and beverages products. Because we are principally needed to protect our population health including young children, youths, adolescents and adults, as well as the health of our future generation; a healthy nation is a wealthy nation.

Acknowledgement

This work was supported by grants from the Ministry of Education Malaysia, Fundamental Research Grant Scheme (FRGS) (No. FRGS/1/2014/SG05/UMS/02/4).

References

[1] A.H. El-Sheikh, Y.S. Al-Degs, Spectrophotometric determination of food dyes in soft drinks by second order multivariate calibration of the absorbance spectra-pH data matrices, Dyes Pigm. 97 (2013) 330–339.
[2] S. Kashanian, S.H. Zeidali, K. Omidfar, N. Shahabadi, Multi-spectroscopic DNA interaction studies of sunset yellow food additive, Mol. Biol. Rep. 39 (2012) 10045–11005.
[3] M. Kucharska, J. Grabka, A review of chromatographic methods for determination of synthetic food dyes, Talanta 80 (2010) 1045–1051.
[4] Y. Xing, M. Meng, H. Xue, T. Zhang, Y. Yin, R. Xi, Development of a polyclonal antibody-based enzyme-linked immunosorbent assay (ELISA) for detection of sunset yellow FCFin food samples, Talanta 99 (2012) 125–131.
[5] European Food Safety Authority (EFSA), EFSA panel on food: scientific opinion on the re-evaluation of Sunset Yellow FCF (E110) as a food additive on request from the European Commission, EFSA J. 7 (2009) 1330.
[6] J.F. Robens, G.S. Dill, J.M. Ward, J.R. Joiner, R.A. Griesemer, J.F. Douglas, Thirteen-week subchronic toxicity studies of Direct Blue 6, Direct Black 38, and Direct Brown 95 dyes, Toxicol. Appl. Pharmacol. 54 (1980) 431–442.
[7] R.A. Medeiros, B.C. Lourencao, R.C. Rocha-Filho, O. Fatibello-Filho, Simultaneous voltammetric determination of synthetic colorants in food using a cathodically pretreated boron-doped diamond electrode, Talanta 97 (2012a) 291–297.
[8] Y.S. Al-Degs, Determination of three dyes in commercial soft drinks using HLA/GO and liquid chromatography, Food Chem. 117 (2009) 485–490.
[9] M. Işik, D.T. Sponza, Fate and toxicity of azo dye metabolites under batch long-term anaerobic incubations, Enzyme Microb. Technol. 40 (2007) 934–939.
[10] S. Fazeli, B. Sohrabi, A.R. Tehrani-Bagha, The study of sunset yellow anionic dye interaction with gemini and conventional cationic surfactants in aqueous solution, Dyes Pigm. 95 (2012) 768–775.
[11] J. Xu, Y. Zhang, H. Zhou, M. Wang, P. Xu, J. Zhang, An amperometric sensor for sunset yellow FCF detection based on molecularly imprinted polypyrrole, Engineering 4 (2013) 159–162.

[12] B.G. Botelho, L.P. De Assis, M.M. Sena, Development and analytical validation of a simple multivariate calibration method using digital scanner images for sunset yellow determination in soft beverages, Food Chem. 159 (2014) 175–180.
[13] K.Y.W. Lok, Y.W. Chung, I.F.F. Benzie, J. Woo, Synthetic colourings of some snack foods consumed by primary school children aged 8–9 years in Hong Kong, Food Addit. Contam. Part B Surveill. 4 (2011) 162–167.
[14] F. Aguilar, R. Crebelli, B. Dusemund, Reconsideration of the temporary ADI and refined exposure assessment for sunset yellow FCF (E 110), EFSA J. 12 (2014) 1–39.
[15] M. Tripathi, S.K. Khanna, M. Das, Surveillance on use of synthetic colours in eatables vis a vis prevention of food adulteration act of India, Food Control 18 (2007) 211–219.
[16] S. Dixit, S.K. Purshottam, S.K. Khanna, M. Das, Usage pattern of synthetic food colours in different states of India and exposure assessment through commodities preferentially consumed by children, Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 28 (2011) 996–1005.
[17] S.P. Alves, D.M. Brum, É.C. Branco de Andrade, A.D. Pereira Netto, Determination of synthetic dyes in selected foodstuffs by high performance liquid chromatography with UV-DAD detection, Food Chem. 107 (2008) 489–496.
[18] N. Saleem, Z.N. Umar, Survey on the use of synthetic food colors in food samples procured from different educational institutes of karachi city, J. Trop. Life Sci. 3 (2013) 1–7.
[19] M.M. Hashem, A.H. Atta, M.S. Arbid, S.A. Nada, G.F. Asaad, Immunological studies on amaranth, sunset yellow and curcumin as food colouring agents in albino rats, Food Chem. Toxicol. 48 (2010) 1581–1586.
[20] N.E. Llamas, M. Garrido, M.S.D. Nezio, B.S.F. Band, Second order advantage in the determination of amarnath, sunset yellow FCF and tartrazine by UV-vis and multivariate curve resolution-alternating least squares, Anal. Chim. Acta 655 (2009) 38–42.
[21] Centers for Disease Control and Prevention (CDC), Mental health in the United States. Prevalence of diagnosis and medication treatment for attention-deficit/hyperactivity disorder-United States, MMWR Morb. Mortal. Wkly Rep. 54 (2005) 842–847.
[22] B. Bateman, J.O. Warner, E. Hutchinson, T. Dean, P. Rowlandson, C. Gant, et al., The effects of a double blind, placebo controlled, artificial food colourings and benzoate preservative challenge on hyperactivity in a general population sample of preschool children, Arch. Dis. Child. 89 (2004) 506–511.
[23] E. Nettis, M.C. Colanardi, A. Ferrannini, A. Tursi, Suspected tartrazine-induced acute urticaria/angioedema is only rarely reproducible by oral rechallenge, Clin. Exp. Allergy 33 (2003) 1725–1729.
[24] D. McCann, A. Barrett, A. Cooper, D. Crumpler, L. Dalen, K. Grimshaw, et al., 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, Lancet 370 (2007) 1560–1567.
[25] H. Mikkelsen, J.C. Larsen, F. Tarding, Hypersensitivity reactions to food colours with special reference to the natural colour annatto extract (butter colour), Arch. Toxicol. Suppl. 1 (1978) 141–143.
[26] R. Sarıkaya, M. Selvi, F. Erkoç, Evaluation of potential genotoxicity of five food dyes using the somatic mutation and recombination test, Chemosphere 88 (2012) 974–979.
[27] K.S. Minioti, C.F. Sakellariou, N.S. Thomaidis, Determination of 13 synthetic food colorants in water-soluble foods by reversed-phase high-performance liquid chromatography coupled with diode-array detector, Anal. Chim. Acta 583 (2007) 103–110.
[28] O. Sha, X.S. Zhu, Y.L. Feng, W.X. Ma, Aqueous two-phase based on ionic liquid liquid–liquid microextraction for simultaneous determination of five synthetic food colourants in different food samples by high-performance liquid chromatography, Food Chem. 174 (2015) 380–386.
[29] X. Ye, Y. Du, D. Lu, C. Wang, Fabrication of β-cyclodextrin-coated poly (diallyldimethylammonium chloride)-functionalized graphene composite film modified glassy carbon-rotating disk electrode and its application for simultaneous electrochemical determination colorants of sunset yellow and tartrazine, Anal. Chim. Acta 779 (2013) 22–34.
[30] S. Lagakos, F. Mosteller, A case study of statistics in the regulatory process: the FD&C Red No. 40 experiment, J. Natl. Cancer Inst. 66 (1981) 197–212.
[31] P. Ashkenazi, C. Yarnitzky, M. Cais, Determination of synthetic food colors by means of a novel sample preparation system, Anal. Chim. Acta 248 (1991) 289–299.
[32] R.D. Combes, R.B. Haveland-Smith, A review of the genotoxicity of food, drug and cosmetic colours and other azo, triphenylmethane and xanthene dyes, Mutat. Res. 98 (1982) 101–243.
[33] FAO. WHO Expert Committee on Food Additives, Specifications for Identity and Purity of Food Colours/as Prepared by the 28th Session of the Joint FAO/WHO Expert Committee on Food Additives, Rome, 1984, pp. 19–28. Relation, 31/1.
[34] H.M. Sayed, D. Fouad, F.S. Ataya, N.H. Hassan, M.A. Fahmy, The modifying effect of selenium and vitamins A, C, and E on the genotoxicity induced by sunset yellow in male mice, Mutat. Res. 744 (2012) 145–153.
[35] P. Seesuriyachan, S. Takenaka, A. Kuntiya, S. Klayraung, S. Murakami, K. Aoki, Metabolism of azo dyes by Lactobacillus casei TISTR 1500 and effects of various factors on decolorization, Water Res. 41 (2007) 985–992.
[36] C.I. Pearce, J.R. Lloyd, J.T. Guthrie, The removal of colour from textile wastewater using whole bacterial cells: a review, Dyes Pigm. 58 (2003) 179–196.
[37] H. Chen, Recent advances in azo dye degrading enzyme research, Curr. Protein Pept. Sci. 7 (2006) 101–111.
[38] R. Bras, A. Gomes, M.I.A. Ferra, H.M. Pinheiro, I.C. Gonçalves, Monoazo and diazo dye decolourisation studies in a methanogenic UASB reactor, J. Biotechnol. 115 (2005) 57–66.
[39] A. Axon, F.E. May, L.E. Gaughan, F.M. Williams, P.G. Blain, M.C. Wright, Tartrazine and sunset yellow are xenoestrogens in a new screening assay to identify modulators of human oestrogen receptor transcriptional activity, Toxicology 298 (2012) 40–51.
[40] A. Yadav, A. Kumar, A. Tripathi, M. Das, Sunset Yellow FCF, a permitted food dye, alters functional responses of splenocytes at non-cytotoxic dose, Toxicol. Lett. 217 (2013) 197–204.
[41] G. Sharma, S. Sharma, A. Dixit, D. Gautam, R.P. Goyal, Effect of kesari powder on haematological and serological parameters in female swiss albino mice, Pharmacologyonline 2 (2010) 425–444.
[42] M.S. Tsuboy, J.P.F. Angeli, M.S. Mantovani, S. Knasmüller, G.A. Umbuzeiro, L.R. Ribeiro, Genotoxic, mutagenic and cytotoxic effects of the commercial dye CI disperse blue 291 in the human hepatic cell line HepG2, Toxicol. In Vitro 21 (2007) 1650–1655.
[43] V.K. Macioszek, A.K. Kononowicz, The evaluation of the genotoxicity of two commonly used food colors: quinoline Yellow (E 104) and Brilliant Black BN (E 151), Cell. Mol. Biol. Lett. 9 (2003) 107–122.
[44] A.A.E. Ibrahim, K.M. Elsherbeny, The genotoxic effect of sunset yellow in somatic and germ cells of the mouse and the protective effect of vitamin C, J. Genet. Eng. Biotech. 1 (2003) 151–161.
[45] C.O. Thompson, V.C. Trenerry, Determination of synthetic colours in confectionery and cordials by micellar electrokinetic capillary chromatography, J. Chromatogr. A 704 (1995) 195–201.
[46] H. Wu, J.B. Guo, L.M. Du, H. Tian, C.X. Hao, Z.F. Wang, et al., A rapid shaking-based ionic liquid dispersive liquid phase microextraction for the simultaneous determination of six synthetic food colourants in soft drinks, sugar-and gelatin-based confectionery by high-performance liquid chromatography, Food Chem. 141 (2013) 182–186.
[47] F. Gosetti, P. Frascarolo, E. Mazzucco, V. Gianotti, M. Bottaro, M.C. Gennaro, Photodegradation of E110 and E122 dyes in a commercial aperitif: a high performance liquid chromatography–diode array–tandem mass spectrometry study, J. Chromatogr. A 1202 (2008) 58–63.
[48] X.H. Chen, Y.G. Zhao, H.Y. Shen, L.X. Zhou, S.D. Pan, M.C. Jin, Fast determination of seven synthetic pigments from wine and soft drinks using magnetic dispersive solid-phase extraction followed by liquid chromatography–tandem mass spectrometry, J. Chromatogr. A 1346 (2014) 123–128.
[49] S. Bonan, G. Fedrizzi, S. Menotta, C. Elisabetta, Simultaneous determination of synthetic dyes in foodstuffs and beverages by high-performance liquid chromatography coupled with diode-array detector, Dyes Pigm. 99 (2013) 36–40.
[50] T.X. Tang, X.J. Xu, D.M. Wang, Z.M. Zhao, L.P. Zhu, D.P. Yang, A rapid and green limit test method for five synthetic colorants in foods using polyamide thin-layer chromatography, Food Anal. Methods 8 (2014a) 459–466.
[51] M. Soylak, Y.E. Unsal, M. Tuzen, Spectrophotometric determination of trace levels of allura red in water samples after separation and preconcentration, Food Chem. Toxicol. 49 (2011) 1183–1187.
[52] B.P. Harp, E. Miranda-Bermudez, C.I. Baron, G.I. Richard, Qualitative identification of permitted and non-permitted colour additives in food products, Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 29 (2012) 886–896.
[53] M. González, M. Gallego, M. Valcárcel, Liquid chromatographic determination of natural and synthetic colorants in lyophilized foods using an automatic solid-phase extraction system, J. Agric. Food Chem. 51 (2003) 2121–2129.
[54] T. Zou, P. He, A. Yasen, Z. Li, Determination of seven synthetic dyes in animal feeds and meat by high performance liquid chromatography with diode array and tandem mass detectors, Food Chem. 138 (2013) 1742–1748.
[55] B.P. Harp, E. Miranda-Bermudez, J.N. Barrows, Determination of seven certified color additives in food products using liquid chromatography, J. Agric. Food Chem. 61 (2013) 3726–3736.
[56] R.S. Razmara, A. Daneshfar, R. Sahrai, Determination of methylene blue and sunset yellow in wastewater and food samples using salting-out assisted liquid–liquid extraction, J. Ind. Eng. Chem. 17 (2011) 533–536.
[57] T.M. Coelho, E.C. Vidotti, M.C. Rollemberg, A.N. Medina, M.L. Baesso, N. Cella, et al., Photoacoustic spectroscopy as a tool for determination of food dyes: comparison with first derivative spectrophotometry, Talanta 81 (2010) 202–207.
[58] M. Khanavi, M. Hajimahmoodi, A.M. Ranjbar, M.R. Oveisi, M.R.S. Ardekani, G. Mogaddam, Development of a green chromatographic method for simultaneous determination of food colorants, Food Anal. Methods 5 (2012) 408–415.
[59] Y. Shen, X. Zhang, W. Prinyawiwatkul, Z. Xu, Simultaneous determination of red and yellow artificial food colourants and carotenoid pigments in food products, Food Chem. 157 (2014) 553–558.
[60] H. Sun, N. Sun, H. Li, J. Zhang, Y. Yang, Development of multiresidue analysis for 21 synthetic colorants in meat by microwave-assisted extraction–solid-phase extraction–reversed-phase ultrahigh performance liquid chromatography, Food Anal. Methods 6 (2013) 1291–1299.
[61] M.H. Sorouraddin, A. Rostami, M. Saadati, A simple and portable multi-colour light emitting diode based photocolourimeter for the analysis of mixtures of five common food dyes, Food Chem. 127 (2011) 308–313.
[62] M.G. Kiseleva, V.V. Pimenova, K.I. Eller, Optimization of conditions for the HPLC determination of synthetic dyes in food, J. Anal. Chem. 58 (2003) 685–690.

[63] M.Ü. Özgür, A rapid spectrophotometric method to resolve a binary mixture of food colorants (riboflavine and sunset yellow), Turk. J. Chem. 28 (2004) 325–334.
[64] R. Wood, L. Foster, A. Damant, P. Key, Analytical Methods for Food Additives, Elsevier, 2004, p. 320.
[65] V.Z. Atayan, E.G. Sumina, S.N. Shtykov, Determination of food dyes by thin-layer chromatography with cyclodextrin mobile phases, J. Anal. Chem. 58 (2003) 642.
[66] F. Soponar, A.C. Mot, C. Sarbu, Quantitative determination of some food dyes using digital processing of images obtained by thin-layer chromatography, J. Chromatogr. A 1188 (2008) 295–300.
[67] B. Tang, C. Xi, Y. Zou, G. Wang, X. Li, L. Zhang, et al., Simultaneous determination of 16 synthetic colorants in hotpot condiment by high performance liquid chromatography, J. Chromatogr. B 960 (2014b) 87–91.
[68] M.S. Garcıa-Falcón, J. Simal-Gándara, Determination of food dyes in soft drinks containing natural pigments by liquid chromatography with minimal clean-up, Food Control 16 (2005) 293–297.
[69] N. Yoshioka, K. Ichihashi, Determination of 40 synthetic food colors in drinks and candies by high-performance liquid chromatography using a short column with photodiode array detection, Talanta 74 (2008) 1408–1413.
[70] E. Diacu, C.P. Ene, A rapid HPLC method for the analysis of water soluble synthetic pigments in soft drinks, Ovidius University Annals of Chemistry 20 (2009) 189–192.
[71] E. Diacu, C.P. Ene, Study of analytical parameters of the HPLC method for tartrazine and sunset yellow analysis in soft drinks, Rev. Chim. (Bucharest) 61 (2010) 1177–1182.
[72] W.J. Li, X. Zhou, S.S. Tong, Q. Jia, Poly N-isopropylacrylamide-co-NN′-methylene bisacrylamide) monolithic column embedded with γ-alumina nanoparticles microextraction coupled with high-performance liquid chromatography for the determination of synthetic food dyes in soft drink samples, Talanta 105 (2013) 386–392.
[73] F.I. De Andrade, M.I. Florindo Guedes, Í.G. Pinto Vieira, F.N. Pereira Mendes, P.A. Salmito Rodrigues, C.S. Costa Maia, et al., Determination of synthetic food dyes in commercial soft drinks by TLC and ion-pair HPLC, Food Chem. 157 (2014) 193–198.
[74] E.C. Vidotti, W.F. Costa, C.C. Oliverira, Development of a green chromatographic method for determination of colorants in food samples, Talanta 68 (2006) 516–521.
[75] K. Asadpour-Zeynali, F. Mollarasouli, Bismuth and bismuth-chitosan modified electrodes for determination of two synthetic food colorants by net analyte signal standard addition method, Cent. Eur. J. Chem. 12 (2014) 711–718.
[76] M.S. El-Shahawi, A. Hamza, A.A. Al-Sibaai, A.S. Bashammakh, H.M. Al-Saidi, A new method for analysis of sunset yellow in food samples based on cloud point extraction prior to spectrophotometric determination, J. Ind. Eng. Chem. 19 (2013) 529–535.
[77] Y.E. Unsal, M. Soylak, M. Tuzen, Column solid-phase extraction of sunset yellow and spectrophotometric determination of its use in powdered beverage and confectionery products, Int. J. Food Sci. Tech. 47 (2012) 1253–1258.
[78] S.S. Mitić, R.J. Micić, R.M. Simonović, Analytical application of food dye sunset yellow for the rapid kinetic determination of traces of copper (II) by spectrophotometry, Food Chem. 117 (2009) 461–465.
[79] Y. Ni, Y. Wang, S. Kokot, Simultaneous kinetic spectrophotometric analysis of five synthetic food colorants with the aid of chemometrics, Talanta 78 (2009) 432–441.
[80] J. Wang, G. Chen, T. Zhu, S. Gao, B. Wei, L. Bi, Identification of tartrazine and sunset yellow by fluorescence spectroscopy combined with radial basis function neural network, Chin. Opt. Lett. 7 (2009) 1058–1060.
[81] N. Sai, Y.P. Chen, N. Liu, G.G. Yu, P. Su, Y. Feng, et al., A sensitive immunoassay based on direct hapten coated format and biotin-streptavidin system for the detection of chloramphenicol, Talanta 82 (2010) 1113–1121.
[82] W.H. Li, M. Meng, F.Y. He, Y.P. Wan, H.Y. Xue, W. Liu, et al., Preparation of an anti-diethylstilbestrol monoclonal antibody and development of an indirect competitive ELISA to detect diethylstilbestrol in biological samples, Sci. Bull. (Beijing) 56 (2011) 749–754.
[83] J.E. Wu, C. Chang, W.P. Ding, D.P. He, Determination of florfenicol amine residues in animal edible tissues by an indirect competitive ELISA, J. Agric. Food Chem. 56 (2008) 8261–8267.
[84] H.C. Goicoechea, A.C. Olivieri, Enhanced synchronous spectrofluorometric determination of tetracycline in blood serum by chemometric analysis: comparison of partial least-squares and hybrid linear analysis calibrations, Anal. Chem. 71 (1999) 4361–4368.
[85] E. Dinc, E. Baydan, M. Kanbur, F. Onur, Spectrophotometric multicomponent determination of sunset yellow, tartrazine and allura red in soft drink powder by double divisor-ratio spectra derivative, inverse least-squares and principal component regression methods, Talanta 58 (2002) 579–594.
[86] M.H. Sorouraddin, M. Saadati, A simple fabrication of portable diffuse reflectometer for simultaneous analysis of common food dyes, Sens. Actuators B Chem. 145 (2010) 367–372.
[87] H. Vargas, E.C. Silva, L.C.M. Miranda, Proceedings of the 13th international conference on photoacoustic and photothermal phenomena, EDP sciences Rio de Janeiro, Brazil, 05–08 July, 2004, J. Phys. IV 125 (2005) 3.
[88] F.J. Liu, C.T. Liu, W. Li, A.N. Tang, Dispersive solid-phase microextraction and capillary electrophoresis separation of food colorants in beverages using diamino moiety functionalized silica nanoparticles as both extractant and pseudostationary phase, Talanta 132 (2015) 366–372.
[89] H.Y. Huang, Y.C. Shih, Y.C. Chen, Determining eight colorants in milk beverages by capillary electrophoresis, J. Chromatogr. A 959 (2002) 317–325.
[90] M. Perez-Urquiza, J.L. Beltran, Determination of dyes in foodstuffs by capillary zone electrophoresis, J. Chromatogr. A 898 (2000) 271–275.
[91] M. Fleischmann, P. Hendra, A. McQuillan, Raman spectra of pyridine adsorbed at a silver electrode, Chem. Phys. Lett. 26 (1974) 163–166.
[92] D.L. Jeanmaire, R.P. Van Duyne, Surface raman spectroelectrochemistry: part I. Heterocyclic, aromatic, and aliphatic amines adsorbed on the anodized silver electrode, J. Electroanal. Chem. Interfacial Electrochem. 84 (1977) 1–20.
[93] M.G. Albrecht, J.A. Creighton, Anomalously intense Raman spectra of pyridine at a silver electrode, J. Am. Chem. Soc. 99 (1977) 5215–5217.
[94] Y. Xie, T. Chen, Y. Cheng, H. Wang, H. Qian, W. Yao, SiO2@Au nanoshells-based SERS method for detection of sunset yellow and chrysoidine, Spectrochim. Acta A Mol. Biomol. Spectrosc. 132 (2014) 355–360.
[95] M. Roosta, M. Ghaedi, R. Sahraei, M.K. Purkait, Ultrasonic assisted removal of sunset yellow from aqueous solution by zinc hydroxide nanoparticle loaded activated carbon: optimized experimental design, Mater. Sci. Eng. C Mater. Biol. Appl. 52 (2015) 82–89.
[96] L.J. Zhao, F.Q. Zhao, B.Z. Zeng, Preparation and application of sunset yellow imprinted ionic liquid polymer–ionic liquid functionalized graphene composite film coated glassy carbon electrodes, Electrochim. Acta 115 (2014) 247–254.
[97] X. Chen, K. Wu, Y. Sun, X. Song, Highly sensitive electrochemical sensor for sunset yellow based on the enhancement effect of alumina microfibers, Sens. Actuators B Chem. 185 (2013) 582–586.
[98] K.J. Huang, Y.X. Miao, L. Wang, T. Gan, M. Yu, L.L. Wang, Direct electrochemistry of hemoglobin based on chitosan–ionic liquid–ferrocene/graphene composite film, Process Biochem. 47 (2012) 1171–1177.
[99] Y. Songyang, X. Yang, S. Xie, H. Hao, J. Song, Highly-sensitive and rapid determination of sunset yellow using functionalized montmorillonite-modified electrode, Food Chem. 173 (2015) 640–644.
[100] M.R. Majidi, M.H. Pournaghi-Azar, R.F.B. Baj, A. Naseri, Formation of graphene nanoplatelet-like structures on carbon–ceramic electrode surface: application for simultaneous determination of sunset yellow and tartrazine in some food samples, Ionics 21 (2015) 863–875.
[101] M. Chao, X. Ma, Convenient electrochemical determination of sunset yellow and tartrazine in food samples using a poly (L-phenylalanine)-modified glassy carbon electrode, Food Anal. Methods (2015) 1–9.
[102] W. Yu, Z. Liu, Q. Li, H. Zhang, Y. Yu, Determination of Sudan I-IV in candy using ionic liquid/anionic surfactant aqueous two-phase extraction coupled with high-performance liquid chromatography, Food Chem. 173 (2015) 815–820.
[103] M. Wang, Y. Gao, Q. Sun, J. Zhao, Sensitively simultaneous determination of sunset yellow and tartrazine in foods based on polypyrrole modified oxidized single-walled carbon nanotubes, J. Electrochem. Soc. 161 (2014) 297–304.
[104] J. Li, X. Wang, H. Duan, Y. Wang, Y. Bu, C. Luo, Based on magnetic graphene oxide highly sensitive and selective imprinted sensor for determination of sunset yellow, Talanta 147 (2016) 169–176.
[105] T. Gan, J. Sun, W. Meng, L. Song, Y. Zhang, Electrochemical sensor based on graphene and mesoporous TiO_2 for the simultaneous determination of trace colourants in food, Food Chem. 141 (2013) (2013) 3731–3737.
[106] X. Qiu, L. Lu, J. Leng, Y. Yu, W. Wang, M. Jiang, et al., An enhanced electrochemical platform based on graphene oxide and multi-walled carbon nanotubes nanocomposite for sensitive determination of sunset yellow and tartrazine, Food Chem. 190 (2016) 889–895.
[107] M.R. Majidi, R.F.B. Baj, A. Naseri, Carbon nanotube–ionic liquid (CNT–IL) nanocamposite modified sol-gel derived carbon-ceramic electrode for simultaneous determination of sunset yellow and tartrazine in food samples, Food Anal. Methods 6 (2013) 1388–1397.
[108] S.M. Ghoreishi, M. Behpour, M. Golestaneh, Simultaneous determination of sunset yellow and tartrazine in soft drinks using gold nanoparticles carbon paste electrode, Food Chem. 132 (2012) 637–641.
[109] T. Gan, J. Sun, S. Cao, F. Gao, Y. Zhang, Y. Yang, One-step electrochemical approach for the preparation of graphene wrapped-phosphotungstic acid hybrid and its application for simultaneous determination of sunset yellow and tartrazine, Electrochim. Acta 74 (2012) 151–157.
[110] M. Gómez, V. Arancibia, C. Rojas, E. Nagles, Adsorptive stripping voltammetric determination of tartrazine and sunset yellow in gelatins and soft drink powder in the presence of cetylpyridinium bromide, Int. J. Electrochem. Sci. 7 (2012) 7493–7502.
[111] R.A. Medeiros, B.C. Lourencao, R.C. Rocha-Filho, O. Fatibello-Filho, Flow injection simultaneous determination of synthetic colorants in food using multiple pulse amperometric detection with a boron-doped diamond electrode, Talanta 99 (2012b) 883–889.
[112] K. Asadpour-Zeynali, S. Manafi-Khoshmanesh, Simultaneous standard addition method for novel determination of components in a single step: application in analysis of sunset yellow and carmoisine by a spectrophotometric technique, Anal. Methods 123 (2014) 228–273.
[113] W. Zhang, T. Liu, X. Zheng, W. Huang, C. Wan, Surface-enhanced oxidation and detection of Sunset Yellow and Tartrazine using multi-walled carbon nanotubes film-modified electrode, Colloids Surf. B Biointerfaces 74 (2009) 28–31.
[114] S. Rouhani, Novel electrochemical sensor for sunset yellow based on a platinum wire–coated electrode, Anal. Lett. 42 (2009) 141–153.