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Determination of Synthetic Dyes in Various Food Samples of Iran's Market and their Risk Assessment of Daily Intake

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THE AIM of this study was to measure the level of synthetic food dyes used in different foodstuffs of Iran's markets via ion-pair high-performance liquid chromatography diode array detector (Ion-Pair HPLC-DAD). The chronic daily intake (CDI), target hazard quotient (THQ) and hazard index (HI) of synthetic dyes for Iranian population were calculated. Based on obtained results, from 74 foodstuff samples tested, only five synthetic dyes (Quinoline, Sunset yellow, Carmoisine, Allura Red and Brilliant Blue) were detected. Sunset yellow was the most commonly used synthetic colorant (45%). The highest concentration of synthetic colors were identified in fruit snacks (361 $mgkg^{-1}$) followed by jelly product (161.9 $mgkg^{-1}$), jelly powder (125.5 $mgkg^{-1}$), ice products (104 mgL^{-1}) and drinks (99.8 mgL^{-1}). To the determine risk of exposure of Iranian consumers to five identified colors in all food product samples the CDI and THQ values were respectively lower than acceptable daily intake (ADI) recommended by WHO/FAO and one. Also, the HI values of all identified colors were lower than one, that did not represent a sever public health risk for synthetic color intake through assessed food samples in Iran's market. Nevertheless, the results highlight the importance of a more attention monitoring of these dyes by the public and food health authorities Iran.

Keywords: Synthetic dyes, Risk assessment, Iran's market.

Introduction

Color is now a food attribute and a major factor in accepting a food [1,2,3]. Food manufacturers therefore try to increase the palatability of healthy functional foods with natural and synthetic colors. Food colors are usually added to foods because they lost their characteristic color during food processing and maintenance [3,4]. Synthetic food colors have many advantages compared to natural colors, such as high stability with respect to light, oxygen and pH, color uniformity. The color of a product is therefore important for its consumer attractiveness [5].

The number of synthetic colors approved for food use differs from one country to another. For example, FAO / WHO Codex Alimentarius has accepted synthetic food colors 14, European Union (EU) 15, USA 9, Japan 12, Korea 9 [6,7,8] and Iran 7. [9]. It should be noted that the Joint FAO / WHO Expert Committee on Food Additives (JECFA) is safe only for food additives that have been assigned an Acceptable Daily Intake (ADI). This was determined on the basis of laboratory animal toxicity tests and human clinical studies. ADI is defined as "an estimate of the amount of a food additive expressed by JECFA on a body weight basis that can be ingested daily

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throughout a lifetime without significant health risk" [10]. This factor ranges from 4 $mgkg^{-1}$ body weight per day for Sunset yellow, Ponceau and Carmoisine to 12.5 $mgkg^{-1}$ body weight per day for Brilliant Blue for approved colors [9] (Table 1). However, azo dyes are widely used in foods because of the cytotoxicity of azo dyes and the potential contribution to carcinogenesis/ mutagenesis of intestinal microbiota reduction in azo dyes, the use of these dyes is less likely to be recommended [1]. Synthetic colors used in industrialized countries to color foods artificially raise health concerns of various degrees. For example, erythrosine causes cancer in animals and Allura Red, Tartrazine and Sunset Yellow can be carcinogenic. There is also evidence that Brilliant Blue, Allura Red and Tartrazine cause allergic reactions and also genotoxicity of tartazin by rodent and microbiological studies , has been reported[12]. Furthermore, in-vitro studies of Azorbin colors show chromosomal changes in the somatic cells of the rye [13]. Lastly, there is a major concern about the use of these colors with little attention and increased disease in children [14]. Previous studies in the production of drinks detected several colors or colors, jelly powders. Gum jelly, chocolate, sweets, ice cream and toffee [15,16].

The aim of the this study was to assess of food dyes in some food samples in Shahrekord (city in south-west of Iran) with selected food types . Estimated intakes were compared to the respective ADIs . Also, the human health risk through consumer was estimated

Materials and Methods

Collection and preparation of sample

Sample collection

A total of six food categories comprising 74 foodstuffs including: various carbonated drinks, edible ice products, jelly powders, candies, fruit leathers and jelly product (postil) were selected as commonly consumed source of synthetic dyes in the Iranian diet(the ingredient of sample was summerised in Table 1). All foodstuffs were purchased of different brands from Shahrekord (city in south-west of Iran).

Sample and Solid phase extraction (SPE) preparation

Preparation of SPE

In order to prepare the cartridge, at first we pass 2 mL Isopropyl alcohol through it and after its exit, we pass 5 mL acetic acid, after its exit cartridge is ready to use. Then the prepared sample (based on the method that is described for sample preparation) is passed through it, in this way, materials such as sugar and other solutions except for dye exit from cartridge, and dye is adsorbed by SPE. Finally we separate dye from cartridge by eluting it with 10 mL of 18% Isopropyl alcohol. Then we separate isopropyl alcohol and water from dye by use of rotary. After adding 3 mL deionized water to remaining dye and passing it through 0.45 μm filter, the sample will be ready to inject into the device.

Liquid samples

Samples of this category were composed of carbonated drinks, fruit carbonated and non-carbonated drinks and edible ice products. For the extraction of dye, 3 ml of the sample was taken and passed it through the SPE (solid-phase extraction) medium. By using the rotary evaporator, isopropyl alcohol and water mixture was separated. Then, 3 ml of deionized water was added to the dye obtained. The sample was passed through a 0.45 μm filter before being injected into a HPLC instrument. It must be noted that carbonated samples were retained in an ultrasonic bath for 20 min. Based on the amount of dye obtained, dilution was done at 1:50 and 1:100 ratios.

Solid samples

Samples of this category were included fruit leathers, jelly powders, candies, and Jelly product (postil) which are water-soluble but in some of them dyes cannot be separated. Therefore, 5 g of the sample was dissolved in a 20:80 mixture of methanol with 10% Ammonium hydroxide. It was maintained in an ultrasonic bath for 20 min, then centrifuged at 4000 rpm for 5 min to separate solid part (in order to have complete separation, 50 mL of methanol/ammonium hydroxide solution was added to the sediments and centrifuged twice or three times). Then 3 mL of clear part was picked up and passed it through SPE. The rest of procedure was the same as that of separation of liquid solutions. Above method was not applied to the candy samples so that they were simply dissolved in water or an aqueous solution. Thus, 5 g of the sample was taken and dissolved in 100 ml of distilled water. Then, 3 mL of the solution was picked up and passed it through SPE.

Analytical methods

Determination of synthetic colorants in foodstuffs by HPLC

HPLC-DAD Procedure

TABLE 1. Specifications of samples

Name of sample	Ingredients on the package
Drink1 (carbonated drinks with orange taste)(diet and non-diet)	Carbonated drinks(Diet) with orange taste: Orange juice, citric acid ,aspartame, acesulfame K, sparkling water, sodium benzoate and sunset yellow Carbonated drinks with orange taste: Orange juice, citric acid, sugar, sparkling water, sodium benzoate and sunset yellow
Drink2 (carbonated drinks with lemon taste)(diet and non-diet)	Carbonated drinks (Diet) with lemon taste: lemon juice, citric acid ,aspartame, acesulfame K, sparkling water, sodium benzoate and Sunset yellow Carbonated drinks with lemon taste: lemon juice, citric acid, sugar, sparkling water, sodium benzoate, Quinoline and Brilliant blue
Drink3 (carbonated drinks with grape)(diet and non-diet)	Carbonated drinks (Diet with grape taste): grape juice, citric acid ,aspartame, acesulfame K, sparkling water, sodium benzoate and Sunset yellow Carbonated drinks with grape taste: grape juice, citric acid, sugar, sparkling water, sodium benzoate and Carmoisine
Drink4 (carbonated fruit drinks	Purified water, sugar, apple juice concentrate, carbone dioxide, citric acid, guarana extract, neutral cloud, papaya flavor, orange flavor, grapefruit flavor, quinolone yellow, allura red
Drink5 (carbonated fruit drinks	Purified water, sugar, apple juice concentrate, carbone dioxide, citric acid, guarana extract, neutral cloud, kiwi flavor, apple flavor, quinolone yellow, brilliant blue
Fruit snake	Fruit puree (apple, data, apricot, plum,…), citric acid, sugar, water
Ice product	Water, fruit flavore, sugar and synthetic addible color
Jelly powder	
candy	
Jelly product	

HP 1090 series II HPLC Agilent instrument with four pumps for liquid chromatographic (LC) analysis was used. The column of Phenomix C18 (250 mm× 3mm with 4 µm particle size) in 40 °C was used to separate the analytes. Mobile phase includes ammonium acetate 0.08 M in water with pH=6 (component A), water 50%, acetonitrile 25%, and methanol 25% (component B). Gradient elution mode begins with A 5% and progresses linearly to B 100% in 20 min. The column is prepared for making ion pair by use of buffer acetate between each analysis. To do so, it is eluted by mobile phase of component A for 5 min. The best flow and volume of injection are 0.5 mL min-1 and 20 µl, respectively. Also used ChemStation software for analysis of the data.

Six different wavelengths were considered for quantitative and qualitative identification of analytes (413 and 427 nm for yellow, 483 nm for orange, 505 and 515 nm for red, and 630 nm for blue). Identification of dyes was done based on retention time and also comparison between different peaks of standard dyes in UV-VIS and peaks of samples that were identified by UV. (Retention time, calibration data including wavelength, correlation coefficient, linear regression, Limit of detection (LOD) and Limit of quantitation (LOQ) for 8 synthetic dyes were shown in Table 2).

TABLE 2. Retention time (t_R), calibration data including λ, correlation coefficient (r), linear regression, Limit of detection (LOD) and Limit of quantitation (LOQ) for 8 synthetic dyes.

Name	$t_{R(min)}$	Calibration data				
		λ (nm)	r	Linear regression	(LOD (mg/kg	(LOQ(mg/kg
Tartrazin	2،7	427	9996،٠	$y = 55.263x + 1.2683$	0.047	0.14
Indigo carmine	5،8	630	9998،٠	$y = 65.482x - 2.6602$	032،٠	0.098
Ponceau 4R	9،5	505	0.9994	$y = 59.019x - 1.1498$	0.058	0.18
Quinoline yellow[a]	10.2 11،1	413	9997،٠	$y = 68.33x + 1.1320$	0.043	0.13
Sunset yellow FCF	10.8	482	9998،٠	$y = 83.598x + 0.8877$	0.036	0.11
Allura red AC	11،9	505	9996،٠	$y = 87.733x + 1.7020$	0.049	0.15
(Carmoisine (Azorbin	14.06	515	0.9996	$y = 83.669x + 1.6267$	0.047	0.14
Brilliant blue	14.8	630	0.9991	$y = 119.49x + 3.9158$	0.07	0،2

[a] Quinolone Yellow has 2 peak at two different time 10.2 and 11.1(min)

Health risk assessment for food dyes

Mean daily intakes (g or mLday^{-1}) of various food groups was considered as follows: various drinks 144 mLday^{-1}, fruit leather 3.8 gday^{-1}, ice products 8.8 gday^{-1}, jelly powder 1.5 gday^{-1} [17], candies and jelly product (postil) 8.3 gday^{-1} [18]. Chronic daily intake (CDI) was determined by the average concentration of each food dye and amount of food consumed per day, calculated using formula 1.

$$CDI = \sum C \times \frac{DI}{BW} \quad (Formula\ 1)$$

Where CDI is chronic daily intake of additive for average consumer (mgkg^{-1}body weight/day), C is mean additive content (mgkg^{-1}), DI is mean food consumption (kg or L day $^{-1}$), BW is average body weight set to 60 kg in this study.

The significant different exposure and overall potential for non-carcinogenic health effects caused by synthetic food dyes, the target hazard quotient (THQ) was calculated using formula 2:

$$THQ = \frac{CDI}{RfD} \quad (Formula\ 2)$$

Where, THQ is target hazard quotient, CDI is chronic daily intake of additive for average consumer (mgkg^{-1}body weight/day), R*f*D is reference dose (mgkg^{-1}bw/day). A significant risk level appears when THQ value is more than 1 (THQ>1) will show. The higher the THQ value, the greater the likelihood of adverse non-carcinogenic health impact [19-20].

The hazard index (HI) from the consumption of synthetic dyes in each food category was calculated as the sum of THQs of all the food samples (FS) and expressed as follows;

$$HI = THQ_{FS\,1} + THQ_{FS\,2} + \ldots + THQ_{FS\,n}$$

The ADI values (as alternative of RfD values) are shown in Table 3 for Tartrazine (E102),Indigo carmine (E132), Ponceau 4R (E124), Quinoline Yellow (E104), Sunset Yellow (E110), Allura Red (E129), Carmoisine (E122), and Brilliant Blue (E133), respectively [9,21,22].

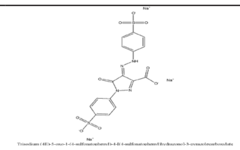
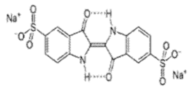
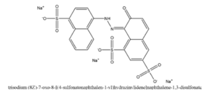
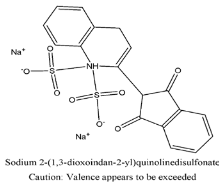
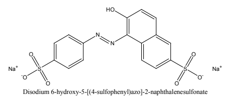
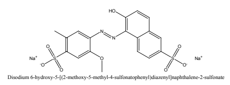
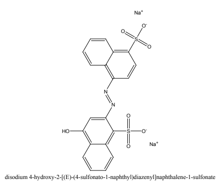
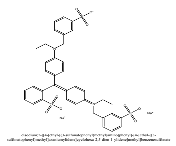
Statistical analysis

Statistical analysis was performed with SPSS Version 18.0 statistic software package. Data were expressed as means ± standard deviation (SD)

Results and Discussion

Of 74 food samples tested, five synthetic dyes including Quinoline, Sunset Blue, Carmoisine, Allura Red and Brilliant Blue were observed. Frequency and concentration of each dye is shown

TABLE 3. Common name, Chemical structure, Appearance, Molecular weight (MW), European community (EC), food, Drug & Cosmetic (FD&C), Acceptable daily intake (ADI)

Compound	Chemical structure	Appearance	(MW(kg	EC	C&FD	ADI(mgkg^{-1} (bw/d
Tartrazin		Yellow powder	534.36	E102	-	7.5
Indigo carmine		purple solid	466.35	E132	Blue 2	7.5
Ponceau 4R		Red powder	604.46	E124	Red 7	4
Quinoline yellow		Greenish yellow powder	477.38	E104	101	5
Sunset yellow FCF		Red orange powder	452.37	E110	Yellow 6	4
Allura red AC		Red powder	496.42	E129	Red 40	7
Carmoisine ((Azorbin		Red powder	502.44	E122	-	4
Brilliant blue		blue powder	792.85	E133	Blue 1	12.5

in Table 4. Based on the analysis performed in food products of the current study, Sunset yellow was the most commonly used synthetic colorant followed by Quinoline and Carmoisine (30.9%), Brilliant Blue (26.2%) and Allura Red (7.1%). Likewise, Lok et al. [23] reported Sunset yellow as a widely used synthetic color in common snack foods consumed by children. Roa et al. [24] from India and Sawaya et al. [25] from Kuwait by have reached the same conclusions.

Among the food products analyzed, highest concentration of synthetic color was identified in fruit snacks (10-361 mgkg-1) followed by jelly product (postil) (13-161.9 mgkg-1), jelly powder (10.5-125.5 mgkg-1), ice products (23-104 mgL-1) and drinks (0.35-99.8 mgL-1), which contained high concentrations of Carmoisine (361mgkg-1), Sunset yellow (161.9mgkg-1), Carmoisine (125.5 mgkg-1), Quinoline (104mgkg-1) , Sunset yellow(99.8 mgkg-1) and Allura red (40.8 mgkg-1) respectively.

Based on Iranian National Standard [26], used of synthetic dyes in not permitted for fruit snacks so all of food products in this category contain impermissible colors. In addition, jelly product (postil) are in the maximum limit range of Sunset yellow (based on the Codex Alimetarius), but it is three times more than the EU.

TABLE 4. Concentration of synthetic dyes in different foods.

Food	E 104				E 110				E 122				E129				E133			
	S/T[a]	min	max	mean±SD	S/T	min	Max	mean±SD	S/T	min	max	mean±SD	S/T	min	max	mean±SD	S/T	min	max	mean±SD
Drinks (mgL^{-1})	10/24	5.7	83.8	30.2±31.6	14/24	2.3	305.8	99.8±99.4	4/24	1.7	38	19.8±25.7	2/24	17.9	46.3	32.1±20.1	4/24	0.2	0.5	0.35±0.21
Fruit snack ($mgkg^{-1}$)	4/8	51.6	286	168±165.7	ND[b]	ND	ND	ND	6/8	130	386	262±128.2	ND	ND	ND	ND	2/8	5.2	14.8	10±6.8
Ice product (mgL^{-1})	2/10	86	135	104.5±27.6	4/10	5	41	23±25.5	6/10	19.1	144	64.4±69.2	ND	ND	ND	ND	ND	ND	ND	ND
Jelly powder ($mgkg^{-1}$)	2/12	8.5	12.6	10.5±2.9	4/12	3.9	67.2	35.5±44.7	6/12	15.2	195.1	125±96.6	2/12	6.7	27.9	17.3±15	2/12	6.7	27.9	17.3±15
Candy ($mgkg^{-1}$)	2/10	15.8	32.7	24.2±11.9	6/10	3.1	45.1	20.7±21.8	ND	ND	ND	ND	2/10	32.1	49.4	40.8±12.2	ND	ND	ND	ND
Jelly product ($mgkg^{-1}$)	6/10	3.8	124.4	64.3±60.3	2/10	136.9	187	161.9±35.4	4/10	10.9	71.5	41.2±42.8	ND	ND	ND	ND	8/10	3.2	31.3	13±13.1

[a] *S* means number of samples that detected dyes in it and *T* means total of sample
[b] ND not detected E102,E124and E132 not detected in different foods.

Base on Codex and EU standards Carmoisine is not permitted in jelly powder, but it is one of seven permitted synthetic colors in Iran with unknown daily intake [27]. In this study, we found a high level of Carmoisine (125.5 mgkg-1) in the jelly powders. While Quinoline is not prohibited in many countries including USA and Europe, it is another permitted synthetic color in Iran. Therefore, based on Iranian National Standard [28] , its concentration in the ice products of the current study was lower than the standard limit. Drinks with high concentrations of Sunset yellow (based on the Codex) are within the permitted limit however, they contain high amount of synthetic dyes when compared with European Standards. Allura Red with a mean concentration of 0.8- 17.3 mgL-1 was observed in the drink samples, jelly powders and candies, which is below the permitted limit. Least concentration level of synthetic dyes (0.35-19.7 mgkg-1) was belonged to Brilliant Blue in the samples of drinks, fruit snacks, jelly powders and jelly product (postil). Table 5 shows limit of permitted synthetic colors based on the Codex, European Standard and Iranian National Standard.

It is revealed that Iranian Standards identify and determine permitted synthetic food colors only so that no limitation has been made on the amount of dye used. This must be considered absolutely in various food products.

Different factors may influence the potential risk of contamination such as artificial color such as per capita consumption of food product, body weight, toxicity, exposure time and etc. therefore, non-carcinogenic risk assessment was done [21, 29].

Chronic daily intake (CDI) of Quinoline with consumption of drinks, fruit snacks, ice products and jelly product (postil) was 0.0725, 0.0101, 0.0156 and 0.009 $mgkg^{-1}bw/day$, respectively which is lower than acceptable daily intake (ADI). This results shows that the amount of Quinoline use by Iranian people is lower than the permitted level (ADI). Since this dye is not permitted to use in many countries, there is little information regarding CDI of this synthetic color in the food products. The highest concentration of Sunset yellow was identified in jelly product (postil) with concentrations of 161.9 $mgkg^{-1}$. While, the CDI of Sunset yellow in all of the food products of the present study was lower than ADI (Table 6). In contrast with our results have been reported in Hong Kong [23], Kuwait [25] and India [24] in which Sunset yellow was the most widely used colorant in drinks and desserts with high concentrations [23].

TABLE 5. Content of synthetic food dyes in different food items vs permitted level in codex alimentarius (CA)[6], EU[7] and Institute of Standard Industrial Research of Iran [26,27,28,35,36]

Dyes		Food category (mgkg^{-1})					
		Drinks	Fruit snack	Ice product	Jelly powder	candy	Jelly product (Postil)
Quinoline yellow	CA	10	Unallowable	Unallowable	Unallowable	Unallowable	Unallowable
	EU	100	Unallowable	150	100	300	100
	ISIRI	unlimited	unallowable	150	unlimited	unlimited	unlimited
Sunset yellow FCF	CA	300	Unallowable	50	300	300	300
	EU	50	unallowable	50	100	50	100
	ISIRI	unlimited	unallowable	150	unlimited	unlimited	unlimited
Carmoisine (Azorbin)	CA	150	Unallowable	Unallowable	Unallowable	Unallowable	Unallowable
	EU	50	Unallowable	50	Unallowable	50	Unallowable
	ISIRI	unlimited	unallowable	150	unlimited	unlimited	unlimited
Allura red AC	CA	300	Unallowable	150	100	300	100
	EU	100	Unallowable	150	Unallowable	300	Unallowable
	ISIRI	Unlimited	unallowable	150	unlimited	unlimited	unlimited
Brilliant blue	CA	150	Unallowable	150	100	300	100
	EU	100	Unallowable	150	Unallowable	300	Unallowable
	ISIRI	unlimited	unallowable	150	unlimited	unlimited	unlimited

Also, the mean amount of Carmoisine in the fruit snacks was 262±128.2 mgkg^{-1} that it was more than the acceptable limit proposed by the ISIRI (Institute of Standards and Industrial Research of Iran). However, the CDI of Carmoisine in all of the food products of the present study was lower than ADI (Table 4). Unlike in our results, Husein et al. [30] in a study on dietary exposure of children to artificial food colors in Kuwait found that the average daily intake of Carmoisine was substantially higher than its ADI.

The results showed that Allura Red in fruit snack, ice product and Jelly product (Postil) samples were not determined (< LOQ=0.15 mgkg^{-1}). Also, the mean concentration of Allura Red in the beverage, Jelly powder and candy were lower than the permissible limit of ISIRI (.150 mgkg^{-1} or mgL^{-1}). The CDI of Allura Red for all food products was lower than ADI (Table 6). Previous study reported that the amount of Allura Red in chocolates did not exceed the amount recommended by CA or EU standards. They showed that the concentration of Allura Red was more in chocolate samples compared to other food products [8]. Doell et al. (2017) demonstrated that for US population and all exposure scenarios, the highest cumulative eaters-only exposures in food were determined for FD&C Red No. 40, FD&C Yellow No. 5 and FD&C Yellow No. 6 [31]. In addition, the amount of daily exposures for children (2.43 ± 0.35 exposures) was higher than adults (0.76 ± 0.15 exposures) for US population [32].

In any sample, Brilliant Blue CDI was not higher than its ADI so that in all samples analyzed CDI≤0.00182. Likewise, Holthe et al. [33] reported that intake of artificial food colorings by children in Amsterdam is limited to Brilliant Blue and is considerably lower than the ADI.

Based on the data collected, it appears that the THQ values in the observed five synthetic food dyes in food product samples was below 1. This suggests that Quinoline, Sunset yellow, Carmoisine, Allura Red and Brilliant Blue in Iranian food groups do not represent a public health risk. However, for Iranian population, the highest THQ values of synthetic colors were

TABLE 6. Exposure estimation of synthetic food dyes in different foods intake in Iranian community

Food	E 104			E110			E122			E129			E133		
	CDI[a] mg/kgbw/day	WCC [b] mg/kgbw/day	THQ [c]	CDI mg/kgbw/day	WCC mg/kgbw/day	THQ	CDI mg/kgbw/day	WCC mg/kgbw/day	THQ	CDI mg/kgbw/day	WCC mg/kgbw/day	THQ	CDI mg/kgbw/day	WCC mg/kgbw/day	THQ
Beverage	0.0725	0.2011	0.0145	0.2395	0.732	0.0595	0.0475	0.0912	0.0119	0.0768	0.1111	0.0192	0.00084	0.0012	0.00007
Fruit snack	0.0101	0.0172	0.0034	-	-	-	0.0157	0.0232	0.0032	-	-	-	0.0006	0.00093	0.00005
Ice product	0.0156	0.0203	0.0031	0.0035	0.0062	0.0009	0.0097	0.0216	0.0024	-	-	-	-	-	-
Jelly powder	0.00026	0.00032	0.00005	0.00089	0.00186	0.00022	0.0031	0.0049	0.00078	0.00043	0.0007	0.00006	0.00049	0.00098	0.00004
Candy	0.0034	0.0046	0.00068	0.0029	0.0063	0.00072	-	-	-	0.0057	0.0069	0.00081	-	-	-
Jelly product (Postil)	0.009	0.0174	0.0018	0.0227	0.0262	0.0057	0.0058	0.010	0.0015	-	-	-	0.00182	0.0044	0.00015
Total	0.0185±0.027	0.043.5±0.0776	0.0235 [d]	0.0539± 0.1041	0.154±0.323	0.0134 [d]	0.0164±0.0181	0.0302± 0.035	0.0039 [d]	0.0276± 0.0426	0.0396± 0.062	0.0067 [d]	0.00094± 0.0006	0.0019± 0.0017	0.00008 [d]

[a] CDI Chronic daily intake (The average concentration of each synthetic dyes was taken as the residue level)
[b] WCC Worst case condition (The maximum concentration of each synthetic dyes was taken as the residue level)
[c] THQ target hazard quotient
[d] HI Hazard index

identified for beverage (0.10517) followed by jelly product (0.00915), fruit snake (0.00665) and ice products (0.0064). Therefore, these products were the main contributing food samples to exposure for multiple synthetic dyes additives for Iranian populations (Fig 1).

For the US population, breakfast cereal, juice drinks, soft drinks, and desserts are considered to be the major contributing food categories to exposure for color additives [32]. Nevertheless, due to regional and cultural differences in food habits, different approaches, methods and also premises used in exposure assessment, it is difficult to compare dietary intake of this study with other studies.

Our results showed that the HI values of all identified colors were lower than 1, nevertheless, the current population is being exposed to a slight potential health risks and suggesting that more attention should be directed toward the ingestion of synthetic food dyes. Use of natural dyes and reduce consumption of food containing artificial food dye are therefore strongly recommended.

In order to reduce food preservatives usage in food industry and increase acquaintance of consumers as to assure human safety, accurate monitoring of synthetic dye amounts via regulatory agencies application of good manufacturing practices (GMP), good hygienic practices (GHP), correct labeling with true information about food must be done [21,34].

Conclusions

The present study investigated seven synthetic dyes in some Iranian food products via an HPLC-DAD method. Dietary intake was also determined based on the food consumption patterns of Iran. In addition, the potential risk associated with the consumption of synthetic dyes was evaluated. The obtained results show that concentrations of five synthetic dyes detected in candies (Quinoline, Sunset yellow, Carmoisine, Allura Red and Brilliant Blue) and three other dyes found in jelly powders (Quinoline, Sunset yellow and Allura Red) all are less than regulatory limits.

It was observed that, the CDI and THQ values for five identified colors in all food products were less than the ADI and one, respectively. Also, the HI values of all identified colors were lower than one, that did not represent a sever public health risk for synthetic color intake through assessed food samples in Iran᾽s market.

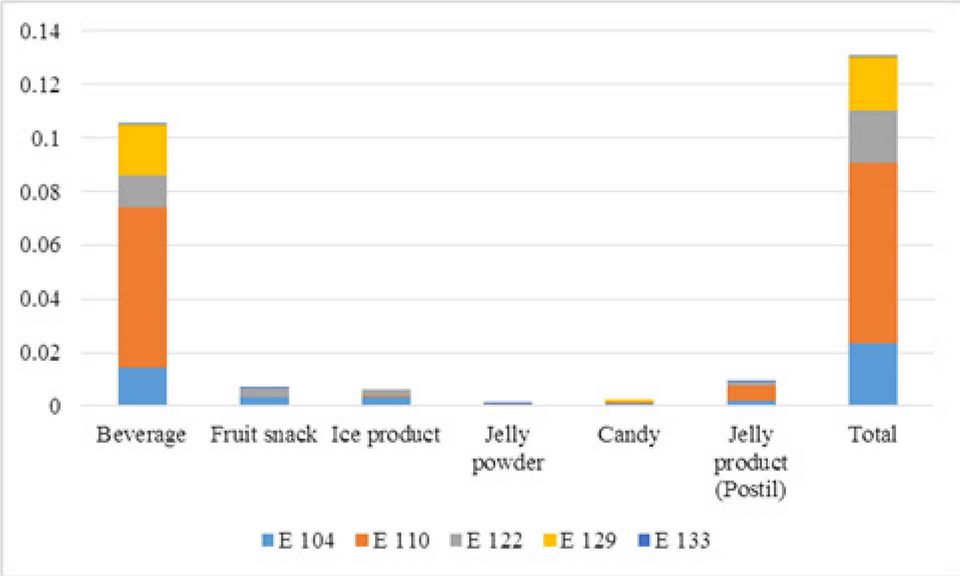


Fig. 1. The comparison of total target hazard quotient of different colors in food stuff separately

Conflict of interest

The authors declare that there is no conflict of interest.

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