All India Survey for Analyses of Colors in Sweets and Savories: Exposure Risk in Indian Population

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Abstract: In the present study, an attempt has been made to understand the exposure assessment of food colors through 2 major groups, sweets and savories, at a national level so as to evolve a scientific yardstick to fix levels of colors in commodities based on technological and safety requirement. A vast majority of colored food commodities (83.6%) were found to employ permitted colors and confirmed a marked decline in the trend of use of nonpermitted colors (NPCs). Of the 4 zones of India, East zone showed the maximum adulteration (80.3%) both by exceeding the prescribed limits of permitted colors (72.3%) and the use of NPCs (28.7%). Tartrazine was the most popular color among the permitted list, which ranged from 12.5 to 1091 mg/kg. Rhodamine B was the most prevalent dye in the NPCs group. On the basis of average consumption of food commodities and average levels of detected colors, the intake of Sunset Yellow FCF saturates the acceptable daily intake limit to a maximum of 47.8% in children, which is a cause of concern. The uniform maximum permissible limit of synthetic colors at 100 mg/kg under the Indian rules thus needs to be reviewed and should rather be governed by the technological necessity and the consumption profiles of food commodities so that the vulnerable population should not unnecessary be exposed to excessive amounts of synthetic colors to pose health risks.

Keywords: color, food additives, food safety, risk assessment, spectroscopy

Practical Application: Many developed countries have collected information on intake of food additives. But in India no national level surveillance on food additives has been conducted in commodities like sweets and savories so far, though some state wise exposure assessment studies have been undertaken. The manuscript shall be useful to collect data on intake of colors from these 2 major commodities as these are frequently consumed by both children and adult population during normal and festive seasons. This may be important for the international agencies during risk analysis processes, since EFSA and JECFA are re-evaluating the acceptable daily intake of some of the permitted food colors.

Introduction

Food colors are stringently screened for safety prior to their use in food commodities. The concept of acceptable daily intake (ADI) provides an indication of safety for use and also enables regulatory authorities to take adequate legislative measures for their control. The calculation of ADI is followed by the authorization of an additive in different foodstuffs and their potential intake (Fondu 1992). Thus the intake data form the baseline information for implementing monitoring programs in order to update the available knowledge on the safety of current exposure to potentially harmful substances in foods or the risk of unbalanced diets (Conacher and others 1989; Turrini and others 1991; Gilsenan and others 2003). Many developed countries have undertaken national level surveillance to collect information on food additives intake (Rhodes and others 1991; Toledo and others 1992; Leclercq and others 1999; FSA 2000; NZFSA 2008). However, there are only a few published exposure assessment studies in developing countries (Hussain and others 2006; Sawaya and others 2007).

The Food Safety and Standards Authority of India permit the use of 8 synthetic colors in specified food commodities at a uniform level of 100 mg/kg or per liter (FSSAI 2012). The ADI of food colors (JECFA 2003), currently approved in India vary from 0.1 to 25 mg/kg body weight per d. Thus, fixing a uniform permissible limit of 100 mg/kg for all food colors in different foods under the Indian rules, irrespective of the technological necessity for a specific preparation, appears unrealistic. This is primarily due to lack of dietary intake data in the Indian context.

In India exposure assessment studies on food additives have been undertaken in some states (Rao and others 2004; Nayak and Nath 2007; Dixit and others 2010). No national level surveillance has been conducted to collect data on intake of colors from various colored foods. Recently, a study was carried out to understand the exposure assessment of synthetic food colors in commodities preferentially consumed by children (Dixit and others 2011). But the commodities like sweets and savories being a major group in itself require attention as well, as these are frequently consumed by both children and adult during normal and festive seasons. Thus an attempt was made to understand the exposure assessment of food colors through these 2 major groups at a national level so as to evolve a scientific yardstick to fix levels of colors in commodities based on technological and safety requirement. Sixteen major states of the country were chosen and the data were generated on the usage pattern of colors and to identify food commodities through which a particular color has a scope of exceeding ADI

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limits. Based on the outcome, regulatory authorities can initiate steps to check excessive exposure of these colors, if any, to safeguard the health in vulnerable population.

Materials and Methods

Reagents

Standards of permitted food colors *viz* Carmoisine, Erythrosine, Indigo carmine, Ponceau 4R, Sunset Yellow FCF (SSYFCF), and Tartrazine were purchased from Hickson and Dadaji (Mumbai, India), while Brilliant Blue FCF (BBFCF) and Fast Green FCF (FGFCF) were the gifts from Bush Boake Allen (Chennai, India). Standards of 6 NPCs *viz* Auramine, Blue VRS, Malachite Green, and Orange II were procured from Vesco products Co. (Kolkata, India); Metanil Yellow was obtained from Lobachemie (Indoaustranal Co., Mumbai, India), and Rhodamine B was the product of the S. D. Fine Chemicals (Mumbai, India).

ExelaR grade acetic acid and liquor ammonia (specific gravity 0.91) were obtained from Qualigens, Mumbai, India. Petroleum ether (GR grade) and trisodium citrate were obtained from Merck Limited, Mumbai, India. Whatman Number 1 chromatography grade paper was procured from Whatman International Ltd., Maidstone, England. All the other chemicals used in the study were of analytical grade and obtained from commercial sources.

Sampling design

Simple random selection technique was followed for sample collection. Four to five cities from each of the 16 states were demarcated and 2 prominent market locations were chosen from each city. Four to five loose samples of each of the 3 colored food commodities, namely milk-based sweets, nonmilk/cereal-based sweets, and savory items were randomly picked up from street vendor retail outlets based on the consumer preferences during food frequency questionnaire (FFQ). The sampling design thus enabled collection of 4 to 5 samples of each commodity from a single market location; 48 samples from each city; 160 samples from each state, and approximately 2560 samples from 16 states. However, nonavailability/damage of some eatables during transportation led to a final pick of 2409 samples, which were kept under refrigeration till further processing.

The intake of colors was assessed through the food frequency recall (FFR) method (Burdock 1996) employing a FFQ, which sought information concerning the respondent's name, age, gender, followed by queries on the consumption and frequencies of intake of specified colored food commodities.

Extraction, clean up, and analysis

The fatty food samples including sweets (both milk- and cereal-based) and fried savories were defatted with petroleum ether followed by extraction with 2% ammonia in 70% ethanol. For non-fried savories, 10 gm samples were soaked in warm water followed by the addition of 2% ammonia in 70% ethanol and kept overnight at room temperature for complete extraction of colors. The extracts having colors were centrifuged, concentrated, acidified with 5% acetic acid and the clean up was performed using wool dye technique. The selective uptake of colors was carried out on pure wool strands (Oswal Company, Mumbai, India) until complete extraction was achieved, followed by washing in running tap water and finally eluting in 5% ammonia solution (DGHS 2005). Pure wool being a protein, act as a zwitter ion and in the presence of acidic or basic medium can pick up specific acidic or basic dyes from the food matrix. Samples were then concentrated to dryness and residues were dissolved in known amounts of 60% ethanol. A known volume (10 μL) of extracted colors and the standard color solutions were applied on to Whatman No. 1 chromatography sheet and developed in trisodium citrate:ammonia:water [2:5:95 (w/v/v)] using ascending paper chromatography (Tripathi and others 2004).

Table 1–Group-wise break up of the surveyed subjects.

Subject group (age in y)*	Male	Female	Total
Children (4 to 12)	151	159	310
Adolescents (13 to 18)	95	114	209
Adults (above 18)	116	156	272
Total	362	429	791

*As per Indian Council of Medical Research (ICMR) report 2000.

For quantitation of detected colors, the resolved spots and the reference standard colors and corresponding blank portions of the chromatogram were cut, eluted in 60% ethanol, and the absorbance was measured at respective λ_{max} employing double beam spectrophotometer (Perkin Elmer Lambda Bio 20, Schwerzenbach, Switzerland). The permitted colors namely, Brilliant Blue FCF, Carmoisine, Erythrosine, Ponceau 4R, Sunset Yellow FCF, and Tartrazine were measured at λ_{max} of 629, 515, 526, 505, 486, and 425 nm, respectively. The NPCs *viz* Auramine, Malachite Green, Metanil Yellow, Quinoline Yellow, Orange II, Rhodamine B, Sudan I, and Sudan III were measured at λ_{max} of 430, 618, 423, 416, 487, 525, 476, and 504 nm, respectively.

Analytical quality assurance

The analytical quality assurance (AQA) data for the method employed to measure the colors showing linearity range, the limit of detection, the limit of quantification, and percentage relative standard deviation (RSD) were generated as described earlier (Dixit and others 2010). The paper chromatography data were also validated simultaneously by analyzing a set of samples on High performance liquid chromatography (HPLC) (Dixit and others 2010).

Surveillance for consumption pattern

A limited household survey on food consumption pattern of 791 subjects was conducted. The subjects were divided into 3 age groups; children comprising 4 to 12 y, adolescents (13 to 18 y), and adult as per Indian Council of Medical Research (ICMR) guidelines (ICMR 2000) (Table 1). Each age group was further subdivided into male and female group.

Intake of colors

The intake of colors was assessed through the FFR method (Burdock 1996) employing FFQ, which sought information of respondent's name, age, gender followed by the queries on the consumption and frequencies of intake of specified colored food commodities. Portion sizes or quantities of food items consumed were recorded in comparison to the standard stainless steel measuring vessels. The type and actual quantity of colors employed in foodstuffs together with the consumption data of respective colored products was used for calculating the intake of food colors. The data were then compared with the respective ADI-based maximum permissible limits of each color and to arrive at the extent of saturation of allowable limits in different age groups.

Actual intake of color (mg/kg bwt) = amount of colored food consumed (g or mL) multiplied by concentration of color present in food (mg/kg), and dividing the product by body weight (kg).

Table 2–Use pattern of colors in 3 group of commodities from different states of India.

Zones & states	Total colored samples	Samples: With permitted colors	Samples: With permitted colors within 100 mg/kg*	Adulterated samples: Due to use of PC above 100 mg/kg	Adulterated samples: Due to use of NPCs	Total adulteration
East						
Assam	127	102	37	65 (63.7)**	25 (19.7)***	90 (70.9)***
Bihar	132	81	32	49 (60.5)	51 (38.6)	100 (75.7)
Orissa	122	74	14	60 (81.1)	48 (39.3)	108 (88.5)
West Bengal	131	108	18	90 (83.3)	23 (17.5)	113 (86.2)
North						
Himachal Pradesh	123	111	44	67 (60.4)	12 (9.7)	79 (64.2)
Punjab	130	116	53	63 (54.3)	14 (10.8)	77 (59.2)
Haryana	120	94	30	64 (68.1)	26 (21.7)	90 (75.0)
Uttar Pradesh	133	108	30	78 (72.2)	25 (18.8)	103 (77.4)
South						
Andhra Pradesh	114	108	54	54 (50.0)	6 (5.3)	60 (52.6)
Karnataka	114	110	49	61 (55.4)	4 (3.5)	65 (57.0)
Kerala	118	109	60	49 (44.9)	9 (7.6)	58 (49.1)
Tamilnadu	121	105	54	51 (48.6)	16 (13.2)	67 (55.4)
West						
Gujarat	121	106	70	36 (34.0)	15 (12.4)	51 (42.1)
Madhya Pradesh	114	100	39	61 (61.0)	14 (12.3)	75 (65.8)
Maharashtra	121	104	55	49 (47.1)	17 (14.1)	66 (54.5)
Rajasthan	110	95	48	47 (49.5)	15 (13.6)	62 (56.4)
	1951	1631 (83.6)	687 (42.1)	944 (57.9)	320 (16.4)	1264 (64.8)

*Maximum allowable concentration of food colors at 100 mg/kg or per litre of food preparation under the Food Safety and Standards Act and Rules of India (FSSR, 2006).
**Values in parenthesis indicate percentage out of total permitted colored samples.
***Values in parenthesis indicate percentage out of total colored samples.

Statistical analyses

Quantity of colors was expressed in terms of range, median and 95th percentile using Microsoft Excel statistical software version 12.0.4518.1014 (Microsoft Office Enterprise 2007).

Results and Discussion

Of the total 2409 analyzed samples, 83.6% eatables contained permitted colors including 58% samples exceeding the maximum allowable concentration (MAC) limit of 100 mg/kg (Table 2). A total of 16.4% samples resorted to the use of NPCs thus amounting to a total adulteration of 64.8%. The range of adulteration due to exceedance of prescribed limits and use of NPCs in the analyzed samples in the 16 states varied from a minimum of 42.1% (Gujarat) to a maximum of 88.5% (Orissa) (Table 2). The adulteration was maximum in the East zone (70.9% to 88.5%) followed by North zone (59.2% to 77.4%). Among individual states, the 2 states of East zone namely, Orissa and Bihar showed maximum use of NPCs to the extent of 39.3% and 38.6%, respectively (Table 2). Orissa (81.1%) also ranked second highest in terms of exceeding the prescribed limit of colors after West Bengal (88.3%). Among 3 states of South zone, the use of NPCs were witnessed below 10%, of which Karnataka showed the least use of NPCs (3.5%) (Table 2).

A vast majority of colored food commodities in the present study were found to employ permitted colors and confirmed a marked decline in the trend of use of NPCs (16.4%) when compared to the previous surveillance studies where the adulteration of NPCs was found in the range of 31% to 60% (Khanna and others, 1985; Dixit and others, 1995; Tripathi and others, 2007). An earlier study conducted by Rao and Bhat (2003) in the state of Karnataka showed 12% usage of NPCs. However, total adulteration (64.8%) whether due to use of excessive levels of permitted colors or due to NPCs is a continued cause of concern.

The commodity wise pattern of permitted and NPCs in all the 4 zones is shown in Table 3. Of all the 3 commodities collected from 4 zones, savories and cereal-based sweets had maximum adulteration (81% to 88%) in the East zone. Moreover, the use of NPCs in milk-based sweets is lower when compared to other 2 commodities collected from the 4 zones and not a single sample of milk-based sweets in South zone encountered NPCs (Table 3).

Table 4 shows the overall usage pattern of various permitted and NPCs and their blends in all the analyzed colored commodities put together. Out of 8 permitted colors in India, only 4 colors were detected in food samples. Erythrosine and Brilliant Blue FCF were used in only a few samples (0.1%), while Indigocarmine and Fast Green FCF (FGFCF) were not encountered in any of the samples. The frequency of use among single colors revealed that Tartrazine (27.5%) was the most popular color followed by SSYFCF (18.3%). The other 2 colors, Carmoisine and Ponceau 4R were found in 4.7% and 3.6% samples, respectively. The levels of Tartrazine detected among all the analyzed samples ranged from 12.5 to 1091 mg/kg followed by SSYFCF (12.0 to 1610 mg/kg), Carmoisine (11.7 to 911 mg/kg), and Ponceau 4R (10.9 to 716 mg/kg). The median levels of use of all the 4 permitted colors invariably exceeded the prescribed limit of 100 mg/kg while 95th percentile levels, exceeded by 5.1 to 6.7 fold. Higher levels of permitted colors have been reported earlier in different states which showed that colors like SSYFCF, Tartrazine, Carmoisine, and Ponceau 4R have exceeded their respective permissible limits by several fold in commodities like sweets and savories (Rao and Bhatt 2003; Rao and others 2004; Hussain and others 2006; Tripathi and others 2007; Dixit and others 2010). This is in contrast to the surveillance studies undertaken in Western countries where only 2% to 6% food preparations were reported to exceed the maximum allowable concentration (MAC) limits (FSA 2000; NZFSA 2008). A vast majority of samples used blend of 2 or more colors; the most common blends were those of Tartrazine plus BBFCF (18.5%); to offer green shade followed by SSYFCF plus Tartrazine (11.5%); SSYFCF plus Carmoisine (5.6%); Carmoisine plus Tartrazine (2.9%); and Carmoisine plus SSYFCF with Tartrazine (2.3%) in the permitted category (Table 4).

Table 3–Commodity-wise pattern of usage of permitted and nonpermitted colors.

			Samples with		Adulterated samples		
Zones	Commodity groups	Colored samples	Permitted colors (PC)	PC within 100 mg/kg*	Due to use of PC above 100 mg/kg	Due to use of nonpermitted colors	Total adulteration (%)
East	Milk-based sweets	85	80	34	46	5	51 (60.0)
	Cereal-based sweets	188	107	22	85	81	166 (88.3)
	Savories	239	178	45	133	61	194 (81.2)
		512	365	101	264 (72.3)	147 (28.7)	411 (80.3)
North	Milk-based sweets	97	87	28	59	10	69 (71.1)
	Cereal-based sweets	190	154	70	84	36	120 (63.1)
	Savories	219	188	59	129	31	160 (73.0)
		506	429	157	272 (63.4)	77 (15.2)	349 (69.0)
South	Milk-based sweets	84	84	71	13	–	13 (15.4)
	Cereal-based sweets	150	143	95	48	7	55 (36.7)
	Savories	233	205	51	154	28	182 (78.1)
		467	432	217	215 (49.8)	35 (7.5)	250 (53.5)
West	Milk-based sweets	88	87	22	65	1	66 (75.8)
	Cereal-based sweets	167	142	104	38	25	63 (38.9)
	Savories	211	176	86	90	35	125 (58.9)
		466	405	212	193 (47.6)	61 (13.1)	254 (54.5)
		1951	1631	687	944 (57.8)	320 (16.4)	1264 (64.8)

*Maximum allowable concentration of food colors at 100 mg/Kg or per litre of food preparation under Food Safety and Standards Act and Rules of India (FSSR, 2006).

Table 4–Use pattern of permitted and nonpermitted colors and their blends in the 3 groups of colored commodities.

			Quantity of colors (mg/kg)		
Color/blends	Total samples	% Frequency	Range	Median	95th Percentile
Permitted					
Single colors					
Tartrazine	448	27.5	12.5 to 1091	142.4	512.5
Sunset Yellow FCF	298	18.3	12.0 to 1610	179.9	537.7
Carmoisine	77	4.7	11.7 to 911	229.5	667.0
Ponceau 4R	58	3.6	10.9 to 716	230.4	634.9
Erythrosine	2	0.1			
Brilliant Blue FCF	2	0.1			
Blend of colors					
Tartrazine + BBFCF	301	18.5	10.8 to 1774	208.9	647.3
SSYFCF + Tartrazine	188	11.5	11.6 to 1198	239.8	737.0
SSYFCF + Carmoisine	92	5.6	18.6 to 1418	276.1	818.0
Carmoisine + Tartrazine	47	2.9	25.9 to 889	219.8	536.1
Carmoisine + SSYFCF + Tartrazine	37	2.3	43.9 to 1071	241.3	679.8
SSYFCF + Tartrazine+ BBFCF	26	1.6	47.9 to 851	234.9	673.3
SSYFCF + Ponceau 4R	21	1.3	31.9 to 1757	414.8	1256.0
Carmoisine + Ponceau 4R	15	0.9	28.2 to 547	239.4	535.9
Other blends*	19	1.2	44.0 to 534	167.0	487.1
Nonpermitted					
Single colors					
Rhodamine B	97	30.3	36.9 to 542	169.0	412.0
Orange II	72	22.5	23.8 to 456	97.6	227.0
Metanil Yellow	41	12.8	36.8 to 256	86.3	162.0
Malachite Green	11	3.4	57.4 to 231	128.5	193.5
Quinoline Yellow	2	0.6			
Auramine	1	0.3			
Blend of colors					
Orange II + Metanil Yellow	29	9.1	39.5 to 358	153.0	297.0
Rhodamine B + Tartrazine	11	3.4	24.0 to 1585	362.2	1036.0
Rhodamine B+ SSYFCF	8	2.5	113 to 269	184.6	267.3
Tartrazine + Metanil Yellow	7	2.2	101 to 551	216.4	450.9
Sudan I + III	8	2.5	36.4 to 102	65.0	97.7
Quinoline Yellow + Tartrazine	6	1.9	71.2 to 200	122.3	186.7
Other blends**	27	8.4	89.3 to 661	200.1	382.4

Other blends* Carmoisine + BBFCF; SSYFCF + BBFCF; Ponceau 4R + Erythrosine; Carmoisine + SSYFCF + BBFCF; Carmoisine + Tartrazine + BBFCF; Carmoisine + SSYFCF + Ponceau 4R; Carmoisine + Ponceau 4R + Tartrazine; Erythrosine + SSYFCF + Ponceau 4R; SSYFCF + Tartrazine + Ponceau 4R; Ponceau 4R + BBFCF + Tartrazine; BBFCF + Tartrazine + Ponceau 4R + Carmoisine; SSYFCF + Tartrazine + Ponceau 4R BBFCF; BBFCF + Tartrazine + SSYFCF + Carmoisine.
Other blends** Orange II + Tartrazine; Orange II + SSYFCF; SSYFCF + Metanil Yellow; Metanil Yellow + Ponceau 4R; Rhodamine B + Carmoisine; Rhodamine B + Ponceau 4R; Metanil Yellow + Tartrazine + Carmoisine; Orange II+ Ponceau 4R + Tartrazine; Tartrazine + BBFCF + OrangeII; Carmoisine + SSYFCF + OrangeII; Tartrazine + BBFCF + Rhodamine B; Orange II + BBFCF + Tartrazine + SSYFCF; SSYFCF + Tartrazine + Rhodamine B; SSYFCF + Tartrazine + Metanil Yellow.

Table 5–Consumption pattern of colored food commodities among subjects of 3 groups.

Food items	Average daily consumption (g)		
	Children	Adolescents	Adults
Milk-based sweets	45 (25 to 100)	59 (25 to 100)	53 (25 to 150)
Cereal-based sweets	74 (25 to 150)	96 (50 to 150)	66.2 (50 to 200)
Savories	52 (36 to 75)	63 (37 to 93)	42 (30 to 120)

Figure in parenthesis shows range of consumption (g). According to ICMR report (2000) children, adolescents, and adults fall in the age group of 4 to 12, 13 to 18, and above 18 y, respectively.

Among NPCs, Rhodamine B (30.3%) was the most prevalent dye in food samples. The other NPCs detected were Orange II (22.5%), Metanil Yellow (12.8%), and Malachite Green (3.4%). Quinoline Yellow and Auramine were used in 0.6% and 0.3% samples, respectively. The blends of NPCs were Metanil Yellow plus Orange II (9.1%); Rhodamine B plus Tartrazine (3.4%); Rhodamine B plus SSYFCF; Sudan I plus Sudan III (2.5%); Tartrazine plus Metanil Yellow (2.2%), and Quinoline Yellow plus Tartrazine (1.9%). The levels of all NPCs used varied between 23.8 and 542 mg/kg with the median and 95th percentile levels showing 86.3 to 169.0 mg/kg and 162.0 to 412.0 mg/kg (Table 4). The study conducted by Rao and Bhatt (2003) showed that NPCs contributed to 10% to 11% in sweet meat and savory items. The use of NPCs, like Metanil Yellow and Orange II was also reported Jonnalagadda and others (2004)from India. The use of blends of Sudan I and III has also been reported earlier (Tripathi and others, 2007). All these NPCs have been shown to cause a wide range of toxic manifestations in experimental animals (IARC 1975; Khanna and Das 1991; Lewis and others 1981; Tsuda and others 2001; Pielesz and others, 2002; Stiborova and others, 2002). The incidence on the use of NPCs in the developed countries is very rare. The presence of Para Red, Orange II, and Sudan dyes have been attributed to only some imported food products (FSA 2005; 2006).

The average consumption pattern of colored food commodities among 3 age groups is given in Table 5. The average consumption per day of colored food commodities was maximum through cereal-based sweets (66 to 74g) followed by milk-based sweets (45 to 59 g) and savories (42 to 63 g) in all the 3 age groups. The mean intake of all the 3 commodities was maximum in adolescent age group due to higher consumption (Table 5).

The intake assessment of food colors in the 3 age group subjects is shown in Table 6. At the average consumption of food commodities and average levels of detected colors (Group-A), the intake of SSYFCF saturated the ADI limit to a maximum of 47.8% in children, 29.4% in adolescent, and 21.2% in the adult group. The intake of Carmoisine and Ponceau 4R saturate the ADI limit to an extent of 27.8% and 24.5% in children. Due to high ADI value of Tartrazine (0 to 7.5 mg/kg bwt), the percent saturation of this color was relatively low (5.7% to 14.9%) in all the 3 age groups.

At the average consumption of food commodities and 95th percentile level of detected colors (Group-B), SSYFCF exceeded the ADI value only in children, whereas the intake in adolescent and adult group saturated the ADI to an extent of 43.1% to 70.2%. Carmoisine and Ponceau 4R tend to saturate up to 69% and 62%, respectively, in the children and in other age groups the intake was relatively low (22.5% to 42.2%). The intake of Tartrazine showed the percent ADI saturation to an extent of 18.2% to 47.6% only in all the 3 age groups. The calculations made at an average consumption of food commodities either with average or with 95th percentile levels of detected colors, the intake of SSYFCF, Tartrazine, Carmoisine, and Ponceau 4R was maximum in children when compared to the other 2 groups (Table 6).

An earlier study performed in the single state of India showed that Tartrazine, SSYFCF, Ponceau 4R, and Carmoisine saturated the ADI limits up to 36%, 62%, 23%, and 5%, respectively, through sweet meats (Rao and Sudershan 2008). Hussain and others (2006) found that the average daily intake of Tartrazine, SSYFCF, and Carmoisine exceeded their respective ADI limits to an extent of 2- to 8-folds through sweet meats in almost all age groups of Kuwait. It is interesting to note that the intake of colors in the majority of Western countries is invariably on a much lower scale. Tartrazine and SSYFCF were found to saturate 0.5% and 2% of their respective ADI in Brazilian children (Toledo and others 1992), while the estimates for Americans were 3% and 8% (IFT 1986) and for Italians 4% and 12% of the permissible ADI (Quattrucci and Saletti 1983). The combined intake of Ponceau 4R, Carmoisine, and Amaranth was found to be 0.2% of the ADI for Swiss children (Hunziker and Zimmerli 1984), while Carmoisine reached the ADI to an extent of 13% to 26% in the Italian population (Quattrucci and Saletti 1983). In Finland, the overall color intake was found to be less than 3% of the ADI in the case of children and less than 1% in the case of adults (Pentilla and others

Table 6–Intake assessment of food colors based on levels detected and consumption of foods.

Food colors	ADI (mg/kg bwt)	Intake of colors in mg/kg bwt/d and % saturation of ADI											
		Children				Adolescents				Adults			
		Male		Female		Male		Female		Male		Female	
		mg/kg bwt/d	% sat	mg/kg bwt/d	% sat	mg/kg bwt/d	% sat	mg/kg bwt/d	% sat	mg/kg bwt/d	% sat	mg/kg bwt/d	% sat
Group A													
SSYFCF	0 to 2.5	1.20	47.8	1.20	47.8	0.67	26.9	0.74	29.4	0.44	17.7	0.53	21.2
Tartrazine	0 to 7.5	1.12	14.9	1.12	14.9	0.63	8.46	0.69	9.23	0.42	5.67	0.51	6.80
Carmoisine	0 to 4.0	1.11	27.8	1.11	27.8	0.63	25.1	0.68	17.1	0.41	16.4	0.49	12.3
Ponceau 4R	0 to 4.0	0.98	24.5	0.98	24.5	0.55	13.7	0.60	15.0	0.35	8.87	0.43	10.6
Group B													
SSYFCF	0 to 2.5	2.84	113.5	2.84	113.5	1.61	64.3	1.76	70.2	1.08	43.1	1.29	51.7
Tartrazine	0 to 7.5	3.57	47.6	3.57	47.6	2.03	27.0	2.21	29.5	1.36	18.2	1.63	21.8
Carmoisine	0 to 4.0	2.75	68.9	2.75	68.9	1.55	38.7	1.69	42.2	1.01	25.2	1.21	30.2
Ponceau 4R	0 to 4.0	2.48	61.9	2.48	61.9	1.39	34.8	1.52	37.9	0.90	22.5	1.08	27.0

Group A: With average levels of colors detected in foods and average consumption.
Group B: With 95th percentile levels of colors detected in foods and average consumption.

1988), which resembled the dietary exposure estimates in New Zealand being less than 5% of the ADI (NZFSA 2008).

Since intake studies give valuable information on exposure risk, the recent studies on Amaranth revealed that its usage through a particular beverage at prescribed levels might exceed ADI by 6-fold (EFSA 2010). This has consequently led to lowering of the ADI of this color to 0.15 mg/kg bwt/d by EFSA against 0.8 mg/kg bwt/d assigned earlier. Similarly based on recent toxicity studies EFSA has decided to reduce the ADI of SSYFCF from 2.5 to 1 mg/kg bwt/d and that of Ponceau 4R from 4.0 to 0.7 mg/kg bwt/d (EFSA, 2009a; 2009bb). If these modified ADI values are taken into account in the present investigation, the intake of SSYFCF and Ponceau 4R will saturate to an extent of 120% and 140%, respectively, in children at the average consumption of food commodities and average levels of detected colors (Group A), which may be a cause of serious concern especially in 3 to 9-y-old children where these colors have been shown to cause hyperactivity and behavioral changes (Mc Cann and others 2007).

Conclusion

Sweets and savories are major food items consumed by all age groups on both normal and festive occasions. The saturation of ADI limits in these commodities up to 48% by a single color is a cause of concern. The uniform maximum permissible limit of synthetic colors at 100 mg/kg under the Indian rules in these commodities thus needs to be reviewed and should rather be governed by the technological necessity and the consumption profiles of the food commodities so that the vulnerable population should not unnecessary be exposed to excessive amounts of synthetic colors to pose health risks.

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