Artificial food color additives and socioeconomic factor: Impact on average daily intake by school children of Saudi Arabia

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Abstract

The average daily intakes of artificial food colors consumed by 6 to 17 years old schoolchildren in Saudi Arabia were estimated on the basis of the average daily consumption of artificially colored foodstuffs by each age group and analytical determination of the levels of artificial colors in these foodstuffs. The results indicated that of nine permitted colors, four exceeded the acceptable daily intakes (ADIs) as set by the Food and Agricultural Organization (FAO)/ World Health Organization (WHO). Statistical analysis was performed to evaluate the influence of various socioeconomic factors on the average daily intake of artificial food colors among these children and data obtained showed significant differences for these parameters.

Keywords: Artificial food colors, analytical determination, average daily consumption, ADIs, children, socioeconomic factors

1. Introduction

Saudi Arabia and other Gulf Cooperation Council (GCC) countries have all undergone tremendous development over the last two decades. The high incomes from oil have enhanced their standard of living several-fold, thus contributing to a very high purchasing power, and a great abundance and diversity of all kinds of foods from all over the world (Sawaya et al., 2008). This rapid change has significantly affected the Saudi lifestyle, particularly in food choices and consumption patterns (Bushnaq et al., 2022).

At present, a wide range of food franchises are prevalent, and eating outside of the home has become habitual. The newly acquired habits of higher sugar consumption and higher consumption of fats, especially animal fats, coupled with more sedentary lifestyles, are known to contribute to the occurrence of several nutrition related diseases, such as coronary heart disease, obesity, and hypertension among others (Popkin, 2006). Sweets (candies, chocolates, toffees, biscuits, chewing gums, etc.) snacks (chips, nuts, puffed snacks, etc.), and many different types of confectionery products now fill the shelves of not only co-ops and supermarkets, but also those of small neighborhood grocery stores. Sweets have become favorites of young children, who are considered to be most likely the major consumers of colored foods. In spite of the lack of data on the local consumption of sweets, snacks, and confectionery products by children, the intake of these products has been increasing dramatically during the last few years, as indicated by unofficial communications with importers of colored food items, e.g., snacks, candies, drinks, etc. Moreover, communications from co-op unions (controlling about 95% of the retail food market in Saudi Arabia), as well as our personal observations show a substantial increase in the shelf space devoted in the country's supermarkets, co-ops, and grocery stores, to sweets, snacks, and other colored food items.

It is expected that the intake of artificial food colors has increased proportionally. In addition, most of the foods consumed in Saudi Arabia are imported from all around the world, including places where quality controls and

regulations are relatively unknown. Many food colors have been banned in the last two decades due to their toxicity, including carcinogenicity (Ghorpade et al., 1995). More recently, there has been renewed concern about the potential toxicological risk associated not only with the type of synthetic colorant used, permitted or not, and the levels, within or above the maximum limits permitted for use, but also with daily exposures to these chemicals in the diet.

The Joint Food and Agriculture Organization and World Health Organization (FAO-WHO) Expert Committee on Food Additives (JECFA) (FAO-WHO, 1989) strongly recommends that governments periodically check the total intake of each and every food additive, particularly those that may pose a potential hazard if their uses are abused and/or if total intakes exceed allowable levels, based on dietary studies at national levels. The purpose of this study was to identify the types and determine the levels of artificial color additives in food products consumed by 6 to 17 years old children in Saudi Arabia, to assess and compare the intake of artificial food colors by these children to the FAO-WHO acceptable daily intakes (ADIs), and to evaluate the influence of different socioeconomic factors on the average daily intake of artificial food colors among these children.

2. Methodology and methods

2.1. Target group

The target population were Saudi schoolchildren between the ages of 6 and 17 years enrolled in private and public primary and intermediate schools (academic year 2014-2015), as they are considered to be the major consumers of foods and drinks containing artificial color additives among the various groups in Saudi population.

2.2. Sample size and structure

The sample size of 5000 schoolchildren was statistically determined as representing the target population ensuring not more than 5% error in the sample estimate at the 95% confidence level. A multi-stage stratified sampling procedure was employed. The overall student population was divided into several subgroups called “strata” covering nationality (Saudi and non-Saudi) and other population characteristics such as sex (males and females), educational levels (primary and intermediate), governorates, school sector (public and private), and age groups (6 to 17 years). Each stratum was considered a separate population and a sample was then drawn independently from each stratum by a random-type procedure taking into consideration distribution. The results of all strata were then combined for the total population of 5000 students.

2.3. 24-Hour Recall

Prior to conducting the field survey, foodstuffs containing artificial color additives (about 839 food items) were obtained from different supermarkets distributed among the governorates in the Saudi Arabia. These food items were grouped into nine categories, namely, biscuits, cakes and ice cream, candy, chips, chocolates, drinks and juices, chewing gum, and jelly. Photographs of food products from all categories were prepared and used by the survey team during the interviews. The dietary survey team, consisting of members from the Department of Food Science and Nutrition, King Saud University, conducted the survey. The team members were thoroughly trained on child interviewing and on the 24-h dietary recall methodology, including data collection and verification. Children were interviewed by the survey team at schools and were asked to recall the types and amounts of colored foods consumed during breakfast, lunch, dinner, and in between the meals during the last 24-h. To facilitate the children’s recall of the amounts of colored foods consumed, the interviewers used photograph album which contained the colored foods available in the market**.**

Procedures for conducting field surveys were followed in accordance with Saudi law. These included the official approvals of Ministry of Education. The questionnaire was designed to obtain information needed for the assessment of the intake of food color additives by 6 to 17 years old school children. Two versions of the survey questionnaire were prepared, one in Arabic and one in English. The questionnaire consisted of the following sections: identification, school information, parental information, child’s height and weight, and food consumed during the

last 24-h. Field survey data for 24-h dietary recall has been statically analyzed using the Statistical Analysis System, Version 9.1.3, (SAS, 2011).

2.4. Artificial color additive levels in foods

Foodstuffs containing artificial colors such as biscuits, cakes and ice cream, candy, chips, chocolates, drinks and juices, chewing gum, and jelly that were identified during the 24-h recall were analyzed. Two packages of each product were mixed and triplicate.

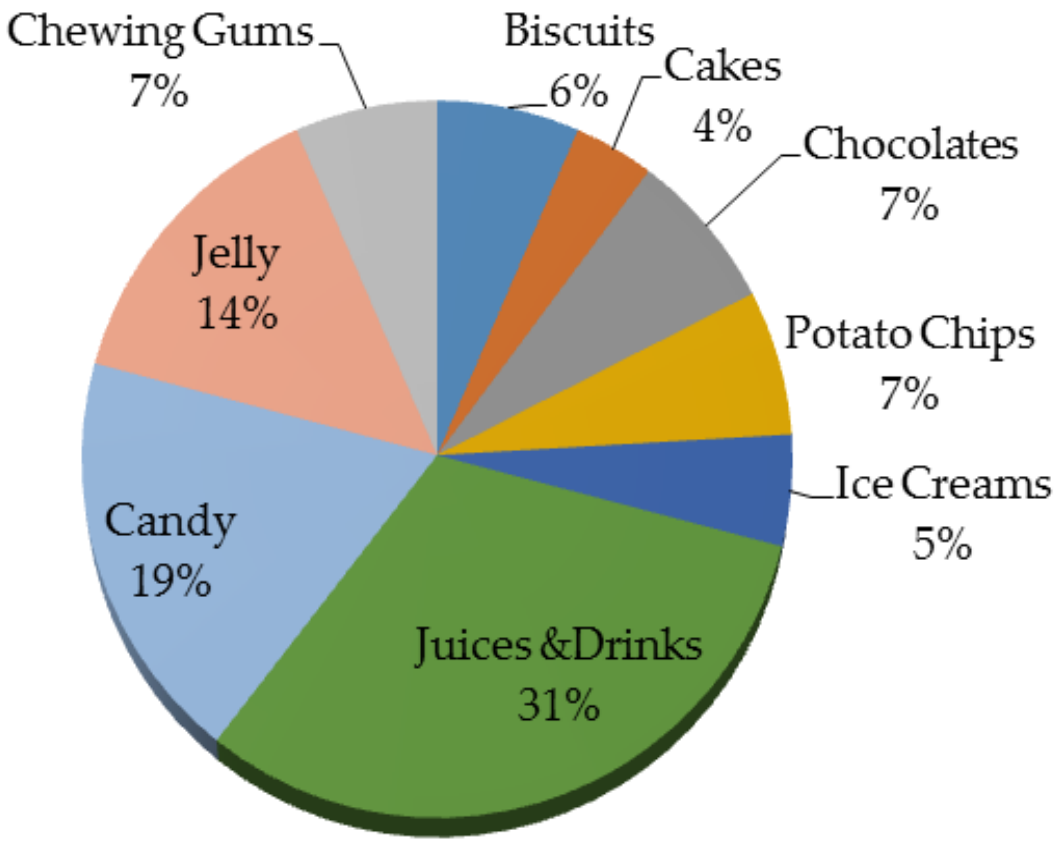

Figure 1. Food category group's percentage distribution of samples.

2.5. Food sample analysis

Perishable food products are stored at 4°C, dry food products (e.g. chips and biscuits) were stored at room temperature, whereas ice cream samples are stored at -20°C up to testing is done. All food products were extracted and analyzed in triplicate.

2.6. Sample preparation (Extraction)

Artificial food color additives were extracted according to the method described by Ha et al. (2013) with some modifications. Briefly, solid samples, such as biscuits, cakes, chips, candy, and jelly (10 g), were crushed, homogenized, diluted with water 2-10-times of volume, color was extracted with heating on a hot plate, chewing gum solid fractions were removed by centrifugation. The sample was dissolved in 50–80% (v/v) ethanol. To prepare high-fat samples, the crushed and homogenized sample (5-10 g) was defatted with petroleum ether prior to color extraction. Carbonated drink samples were sonicated for 5 min to remove gas. Volume reduction was adjusted with distilled water, then additional (10 mL) distilled water was added.

The ice cream samples were prepared according to the method described by Del Giovine and Piccioli Bocca (2003). Ice cream (10 g) was weighed in a beaker, and ammonical ethanol (30 mL) (EtOH + 5% conc. NH4OH mixture) was added. The sample was allowed to rest in a refrigerator to ease separation of the thickeners. The sample was then filtered, and the colored liquid was collected in a 100 mL volumetric flask. The extraction was repeated twice with ammonical ethanol (15 mL), and the liquid was collected in the calibrated volumetric flask each time. Then the required volume was obtained by adding water. The resultant solutions were filtered through a 0.45 µm membrane prior to high performance liquid chromatography (HPLC) injection.

2.7. Instrumental analysis

Samples are analyzed for synthetic food color additives using Agilent Technologies, RP-HPLC, reversed phase high performance liquid chromatograph with the following details: column, Zorbax Sb-C18 (250 x 4.6 mm, 5 µm), detector 1260 DAD-VL. Ammonium acetate 10 nM solution mobile phase A and acetonitrile mobile phase B with flowrate of 1 mL/min with optimized gradient program (A:B) initially 95:5, at 30 min 50:50 at 30.1 min 95:5. The absorbance was monitored at 426 nm for Tartrazine (E102), 482 nm for Sunset Yellow (E110), 514 nm for Carmoisine (E122), 530 nm for Erythrosine (E127), 509 nm for Allura Red (E128) and Red 2G (E128), 613 nm for Indigo Carmine (E132) and Black PN (E151), and 628 nm for Brilliant Blue (E133) and Fast Green FCF (E143). Peaks were identified and quantified using the retention time of standards absorption spectra.

3. Results and discussion

3.1. Target sample size

A sample size of 5000 children, aged 6-17 years (2509 male and 2491 female), from primary and secondary schools in Riyadh, Saudi Arabia, representative of the target population was statistically determined and no more than 5% error estimated at 95% of the confidence level was ensured. Details of each governorate sample size were as follows: (boys) north 550, south 537, east 495, west 496, and central 431, and (girls) north 360, south 319, east 735, west 566, and central 511.

3.2. Pattern of consumption of food products

Among the nine food categories, juices and drinks, ice cream, and cakes were highly consumed by school-going male and female children, as observed in Table 1. Based on the food frequency questionnaire, chewing gum was not consumed as much. Male school-going children of all age groups consumed solid foods and liquids containing artificial color additives daily in the following ranges: biscuits 36-58 g, cakes 52-69 g, chocolates 40-53 g, potato chips 33-44 g, ice cream 93-238 g, juices and drinks 304-442 mL, candy 23-68 g, jelly 16-57 g, and chewing gum 4-9 g. However, the female school-going children consumed food and beverages with artificial color additives daily in the following ranges: biscuits 35-50 g, cakes 45-63 g, chocolates 35-47 g, potato chips 39-62 g, ice cream 114-223 g, juices and drinks 283-314 mL, candy 13-36 g, jelly 31-74 g, and chewing gum 4-8 g.

Table 1. Intake of food containing artificial color additives by school-going children in Saudi Arabia (g/day).

Age (years)	6 - 7		8 - 9		10 - 11		12 - 13		14 - 15		16 - 17	
Food category	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Biscuits	40.80	50.33	48.05	38.73	58.30	35.05	50.52	41.10	40.23	45.78	35.59	38.46
Cakes	67.80	44.72	51.60	47.73	52.79	55.31	54.26	56.62	63.72	56.77	69.08	62.67
Chocolates	44.50	42.51	52.60	35.37	46.24	40.15	45.14	44.10	45.31	46.16	40.05	47.13
Potato chips	32.90	38.68	33.71	43.27	37.48	55.88	37.02	59.15	43.66	52.53	34.23	62.37
Ice cream	0.00	215.61	93.00	184.33	238.26	188.46	218.26	214.35	141.61	222.81	141.50	113.80
Juices and drinks	366.00	298.41	322.86	283.05	303.99	303.93	353.21	314.13	355.44	299.73	441.56	313.82
Candy	0.00	22.73	68.32	18.62	41.12	35.21	27.99	35.76	23.13	13.27	64.00	15.54
Jelly	0.00	31.14	19.33	38.36	57.04	58.91	31.54	57.98	49.25	73.69	16.27	0.00
Chewing Gum	0.00	8.13	6.71	4.48	8.48	4.26	4.93	3.74	4.24	4.52	4.55	4.88

The percentage distribution of the food items, in the various analyzed food categories, tested for artificial color additives are shown in (Figure 3). It was found that the most commonly used artificial food color additives were Brilliant Blue (E133) (54.1%) and Tartrazine (E102) (42.3%), followed by Sunset Yellow (E110) (39.1%), Allura Red (E129) (33.9%), Carmoisine (17.5%), and Fast Green FCF (16.2%).

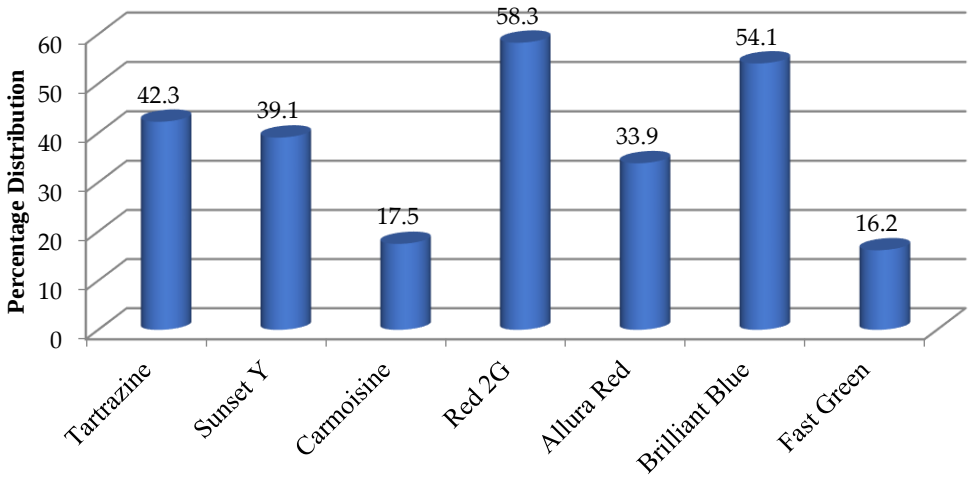

Figure 2. Percentage distribution of artificial food color additives in the studied categories.

3.3. Pattern of consumption of food products

The trend of food intake observed in this study was similar to that reported in a study (French et al., 2003) on national trends of soft drink consumption among 6-17-year-old children in the United States. The study showed a 48% increase. Rao et al., (2004) reported intake of beverages in the range of 25-540 mL and 32-840 mL by 1-5-year-old and 6-18-year-old children, respectively, in India. The beverages fruit drinks, squashes, and sherbets are consumed by both age groups.

3.4. Level of artificial color additives in food products commonly consumed by school-going children

Artificial food color additives use in Europe is strictly regulated and harmonized with the formulation of Directive 94/35/EU (Minioti et al., 2007). In Saudi Arabia, the use of synthetic colors in food follows the GCC Food color standard 285/1999, which is currently being updated by the Saudi food and drug authority, SFDA.
Many tested samples did not contain food color additives, and this could be due to the below detection levels of the additives or use of natural colors, as confirmed by the E numbers listed on the label. Rao and Bhat (2003), studied the synthetic food colors types and levels in the food products of Hyderabad city and its surrounding areas. Out of the 1000 food items (700 from urban areas and 300 from rural areas) collected and analyzed, 7% of the foods from urban areas and 5% of the foods from rural areas contained non-permitted color additives. In beverages, such as artificial syrups and sherbets, the concentrations of Tartrazine (E102) and Sunset Yellow (E110) were 9.45 mg/g and 4.57 mg/g, respectively.

In another study conducted by Jonnalagadda et al. (2004), 545 ready-to-eat foods prepared in the non-industrial sector were investigated. The data obtained showed that 73% of the samples exceeded 100 ppm, whereas 27% are within the approved limit set by Indian Prevention of Food Adulteration (PFA) Act (1954) for the permitted synthetic colors.

3.5. Average Daily Intake of Artificial Food Colors and Socioeconomic Factors

To evaluate the influence of certain parameters, including governorate, school sector, educational level, nationality, age, sex, and employment status of the father and mother, on the average daily intake of artificial food

colors among 6- to 17-year-old schoolchildren in Saudi Arabia, analysis of variance (ANOVA) was performed using the SAS, and the results are presented in Tables 2, 3 and 4

As shown in Table 2, the average daily intake of artificial food colors by children in the different governorates were significantly different. Despite the fact that schoolchildren in the different governorates are exposed to similar foods, which are very abundant in supermarkets, and groceries.

Table 2. Influence of age on the ADI of artificial food color additives (mg/kg body weight).

Age (Years)	ADI
6	1.824
7	1.947
8	1.437
9	1.324
10	1.177
11	1.088
12	1.111
13	0.995
14	0.87
15	0.818
16	1.003
17	0.587

Table 3. Influence of governorate and school sector on the ADI of artificial food color additives (mg/kg body weight).

Location	ADI
Center	1.021
North	1.030
East	0.945
South	1.252
West	1.2
School Sector	
Government	1.098
Private	1.085
International	1.080

The influence of school sector, educational level, and nationality on the average daily intake (ADI) of artificial food colors among schoolchildren. There were significant differences between children from public and private schools, i.e., children in private schools showed a lower intake of artificial food colors compared to children from public schools. The higher artificial food color intake of children in public schools could be due to a culture of greater awareness in private schools than exists in the public schools, or perhaps due to greater parental guidance of private-school children. Children in primary schools had significantly higher intakes of artificial food colors than children in intermediate schools, possibly due to less awareness at the younger age level than the older groups. Also, the intake of synthetic food colors by Saudi schoolchildren was significantly greater than that of non-Saudi. The higher intake of artificial food colors among schoolchildren in public schools could be due to the higher purchasing power of Saudi versus expatriates, and perhaps to a general lack of nutritional awareness among Saudi.

Table 4. Influence of education, nationality and gender on the ADI of artificial food color additives (mg/kg body weight).

Educational Level	ADI
Primary	1.174
Intermediate	0.912
Nationality	
Saudi	1.107
Non-Saudi	1.057
Gender	
Boys	1.066
Girls	1.121

Females had significantly higher average daily intakes of artificial food colors than males. This may be due to the more sedentary lifestyles of the females than the males, and subsequently, greater intake of drinks, snacks, and other foods that contain artificial color additives. Age was found to have a significant effect on the average daily intake of artificial food colors, especially among children 5 to 8 years old, who showed significantly higher average daily intakes of artificial food colors than the other age groups. Since the average daily intake is calculated based on body weight, and children at these age groups have lower body weights than children in the other age groups, one might postulate that the intake of artificial colorants tends to be more visible in children 5 to 8 years old than in older children, in addition to the fact that artificially colored foods such as snacks and sweets are more highly favored by younger children than by older ones.

4. Conclusion

Results of this study demonstrated that the intake of ice-cream (44%) and juices and drinks (30%) are higher by school going children of 6-17 years of age. Sunset yellow was detected in higher concentrations by HPLC in food products. Average daily intake (ADI) was the highest (1.947 mg/kg body weight) in 7 years old whereas 0.587 mg/kg body weight was the lowest by 17 years old school going children. In general ADI for all ages, boys were lower than the girls. In light of these findings it is utmost important to pay attention by the manufacturers and regulatory authorities to implement interventions measures to reduce their health implications.

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