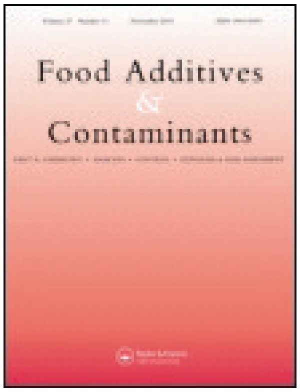

Food Additives & Contaminants: Part A
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tfac20

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Available online: 10 Dec 2009

To cite this article: A. Connolly, Á. Hearty, A. Nugent, A. McKevitt, E. Boylan, A. Flynn & M.J. Gibney (2010): Pattern of intake of food additives associated with hyperactivity in Irish children and teenagers, Food Additives & Contaminants: Part A, 27:4, 447-456

To link to this article: http://dx.doi.org/10.1080/19440040903470718

Food Additives and Contaminants
Vol. 27, No. 4, April 2010, 447–456

Pattern of intake of food additives associated with hyperactivity in Irish children and teenagers

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(*Received 21 September 2009; final version received 2 November 2009*)

A double-blind randomized intervention study has previously shown that a significant relationship exists between the consumption of various mixes of seven target additives by children and the onset of hyperactive behaviour. The present study set out to ascertain the pattern of intake of two mixes (A and B) of these seven target additives in Irish children and teenagers using the Irish national food consumption databases for children ($n = 594$) and teenagers ($n = 441$) and the National Food Ingredient Database. The majority of additive-containing foods consumed by both the children and teenagers contained one of the target additives. No food consumed by either the children or teenagers contained all seven of the target food additives. For each additive intake, estimates for every individual were made assuming that the additive was present at the maximum legal permitted level in those foods identified as containing it. For both groups, mean intakes of the food additives among consumers only were far below the doses used in the previous study on hyperactivity. Intakes at the 97.5th percentile of all food colours fell below the doses used in Mix B, while intakes for four of the six food colours were also below the doses used in Mix A. However, in the case of the preservative sodium benzoate, it exceeded the previously used dose in both children and teenagers. No child or teenager achieved the overall intakes used in the study linking food additives with hyperactivity.

Keywords: exposure; exposure assessment; risk assessment; survey; colours; processed foods

Introduction

In 2008, the European Union introduced new legislation with regards to the use of food additives (Regulation (EC) No. 1333/2008; European Commission 2008). This new legislation stipulates that any food on sale in the European Union that contains particular food additives (Sunset Yellow, Carmoisine, Tartrazine, Ponceau 4R, Allura Red, and Quinoline Yellow) be labelled to indicate that these additives 'may have an adverse effect on activity and attention in children' (European Commission 2008). This change in legislation was adopted on 16 October 2008, published on 31 October 2008 and entered into force on 20 January 2009. It will apply from the 20 January 2010. Foods entering the market or labelled before this date that do not comply may be marketed until their date of minimum durability or the use-by-date. This development arose from a study based in Southampton, UK, which showed that either of two mixes of food additives administered to children daily over 1 week increased the risk of developing hyperactive behaviour (McCann et al. 2007). The study was a double-blind, randomized-controlled study and was subsequently analysed by two independent committees of experts: the UK Committee on Toxicology (2007) and the European Food Safety Authority (EFSA) (2008), and both fully accepted the validity of the study. The present paper does not attempt to negate or contest the findings of that study that clearly showed that a given hazard (either of two mixes of five food additives) elicited an adverse effect (hyperactive behaviour) in a given population (children). What the present study is attempting to do is to add to risk-assessment data by examining the probability that the hazard in question actually occurs in a nationally representative sample of Irish children and teenagers. The Irish food consumption databases are particularly suited to this purpose since all food intake data are collected at brand level. The collection of branded data is to allow the maintenance of The Irish National Food Ingredient Database (INFID), which records all ingredients of branded foods consumed in the various food consumption surveys (Gilsenan et al. 2002).

The INFID has many uses such as identifying which foods contain specific ingredients and thus it was used to establish human exposure to dioxin in the

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ISSN 0265–203X print/ISSN 1464–5122 online

DOI: 10.1080/19440040903470718
http://www.informaworld.com

recent Irish pork dioxin incident. In the case of food additive intake estimates, the great strength of the INFID is its use to assign accurately the true presence or absence of a target food additive in a given food. Normally, in the absence of such data, the estimation of food additive intake must necessarily assume that if an additive can legally be present in a food it will always be present. The INFID also allows for the exploration of the simultaneous ingestion of given food additives whether from one food or from several foods. Thus, the present paper is intended to inform the risk-assessment process on the pattern and level of usage of the food additives used in the Southampton study.

Materials and methods

The Irish National Food Ingredient Database (INFID)

Patterns of additive intake by Irish children and teenagers were assessed using the INFID. The INFID is a multifaceted database developed in Microsoft Access that stores information on the ingredients of 1859 foods eaten in the Irish diet. This information was obtained alongside two national dietary surveys: The National Children's Food Survey (NCFS) (2003–2004) and the National Teen Food Survey (NTFS) (2005–2006). The NCFS surveyed 594 children aged between 5 and 12 years and the NTFS surveyed 441 teenagers aged between 13 and 17 years. Both surveys collected quantitative food intake data using 7-day food diaries along with physical activity measurements, lifestyle and attitude information. A detailed account of the methodology used in both surveys is available elsewhere (Irish Universities Nutrition Alliance 2009). The INFID is updated regularly, having been updated in 2004 (during the NCFS), 2007 (during the NTFS), and is currently being updated as part of a new national food survey. However, when analysing the usage patterns for the present study, ingredient data were used from INFID that related to the time frame of the Southampton study (2007).

All packaging belonging to foods consumed during the survey period were collected by the participants and given to the fieldworkers conducting the surveys. This packaging was then forwarded to the coordinating centre in University College Dublin. Using this packaging, general information about the food was recorded in INFID, such as the brand name, product description, product weight, and country of origin of the food. Ingredient lists for every product were also recorded from the package label, as well as the nutritional information of each product. A composite food and ingredient table also recorded information on the composite ingredients in the products, e.g. ingredients for the jam of a biscuit.

All food intake data in the surveys were collected at brand level, and unique brand identification codes were assigned to separate branded food items and these differed per flavour per product type. This resulted in 5551 different brand codes for the children and 4921 brand codes for the teenagers. Details of all ingredients per food item consumed were entered into the INFID and coded using unique brand identification codes to link with the food consumption databases. Ingredients were also identified by unique ingredient identification codes, which allowed the INFID to be searched for a specific ingredient. For example, when INFID was explored to ascertain the occurrence of Sunset Yellow (E 110) in foods consumed by the children and teenagers, the ingredient table was searched for its unique ingredient code. This produced a list of all the products and brand identification codes that contained this food colour.

Food consumption data

Food consumption data from the NCFS and the NTFS were exported from the dietary analysis software WISP© (Tinuviel Software, Anglesey, UK) and exported as food files into SPSS (SPSS v.12; SPSS, Inc. Chicago, IL, US). Each row in the food files corresponded to the weight and the nutrient breakdown of each food consumed per each eating occasion per day per subject. All foods consumed were also coded at brand level, thus each food was linked to a brand identification code as per the INFID. Information on the day of the week and on the type of meal, e.g. breakfast, was recorded. The NCFS food file contained 72 024 rows and the NTFS food file contained 46 473 rows of data.

Assessing additive intake

Based on the assigned brand identification codes per food in the food files, it was possible to establish the food ingredients associated with each food-eating occasion, such as food additives, based on the ingredient lists in INFID. More than one additive may have been present per branded food product consumed.

The INFID was then explored to determine the probability of the intakes of different combinations of seven additives in the diets of Irish children (NCFS) and teenagers (NTFS). The present study focused on the seven food additives used in the Southampton study: Sunset Yellow (E 110), Carmoisine (E 122), Tartrazine (E 102), Ponceau 4R (E 124), Allura Red (E 129), Quinoline Yellow (E 104), and Sodium Benzoate (E 211).

Categorization of foods

For the purpose of exposure assessment, all foods consumed by the survey participants were categorized into food groups in which these seven additives are legally permitted, as outlined in European Union legislation (Directive No. 94/36/EC – European Union 1994; and Directive No. 95/2/EC – European Union 1995). These Directive food groups detail the maximum permitted level (MPL) of each additive per food group (in $mg\,kg^{-1}$ food). These groups were developed by categorizing foods consumed in the SPSS food files according to the appropriate food group outlined in the legislation. If a food comprised of more than one component that may contain the additives (i.e. composite foods), the separate components were put into separate food groups. For example, an iced doughnut would be categorized into both the 'Fine bakery wares' group (doughnut) and the 'Decorations and coatings' group (icing). This resulted in 36 food groups for food colours and 34 groups for Sodium Benzoate.

The additive intake for each participant was then estimated by multiplying the consumption level of each food group where the target additives were present (identified from the INFID) by the additive concentration based on the MPL. When the additive was absent from a food, the exposure was always zero. Creme software was used to handle all the data sets and to conduct the exposure assessments (Creme Software 'Creme Food', Creme Software Ltd, available from: http://www.cremesoftware.com/; accessed 10 July 2009). These assessments were run by uploading information from the NCFS and the NTFS into the Creme software. This information included the raw food intake data from the survey diaries (on all eating occasions), European Union Directive food groups, and the true occurrence of the target additives in those food groups.

The mean daily intake of each food additive for children and teenagers was used to construct a distribution from which the mean, 5th and 97.5th percentiles of additive intakes were computed. Considering each food additive separately, participants who did not consume the target additives in the course of the 7-day study were excluded so that all intake estimates presented are for consumers only. Analysing 'consumer-only' data ensured that the worst-case exposure was computed as this prevents the reduction of intake estimates by the otherwise inclusion of individuals with no intake of the additive.

The average age of the children in this study was 8.5 years, which allowed their intakes to be compared with the doses given to the 7–8-year-olds in the Southampton study. In that study, the additive dose used for this age group was partly based on a multiple of a younger group (3 years of age) because of their higher energy requirements. In the present study, the average intake of energy among the teenagers (mean age = 15.4 years) was 1.2 times that of the children, and thus in the present study the Southampton doses could have been adjusted upwards pro rata. However, by keeping with the lower dose applicable to 8–9-year-olds with lower-energy intakes, this allowed a conservative approach to be adopted for the exposure assessments to the target additives in the adolescent sample.

Results

Probability of occurrence (in foods and meals)

By availing of the data recorded in the INFID at brand level, frequencies of target additive consumption for the children and teenagers were calculated. With 594 children and 441 teenagers surveyed over 7 days, this resulted in 4158 child-days and 3087 teen-days. Arising from these, 72, 024 eating occasions were consumed by the children and 46, 473 by the teenagers. These are known as food-eating occasions. Further to this, 19, 795 eating occasions (meals and snacks) were recorded for the children and 13, 541 for the teenagers. These are referred to as meal-eating occasions in the present study.

Table 1 lists the frequency of foods eaten by Irish children and teenagers containing one or more of the target food additives. The majority of additive-containing food-eating occasions for both children and teenagers only contained a maximum of one of the target additives (3.8% for the children, 3.1% for the teenagers). There were totals of 5551 unique brand codes in the children's database and 4921 in the teenagers. Of these, the vast majority did not contain any of the target additives, i.e. 94.8% for the children and 96.2% for the teenagers. Of those brands that contained the target additives, 279 (5%) of the children's branded foods contained at least one of the target additives, with 194 (3.9%) for the teenagers (data not shown). In the case of children, no food-eating occasion ever contained five or more of the target additives, and in the case of teenagers no food contained any six of the target additives.

A similar trend is followed when looking at additive consumption in terms of meals. Table 2 presents the frequency of meal-eating occasions by Irish children and teenagers that contained at least one of the target additives. Again, the majority of meals for both populations contained at least one of the target additives. As the number of foods per meal-eating occasion decreased, the presence of an additive-containing food increased, reflecting the high occurrence of additives in snack-foods eaten alone.

Table 1. Frequency of food-eating occasions containing one or more of the target additives in 594 children (aged 5–12 years) and 441 teenagers (aged 13–17 years).

Number of target additives	Number of teenagers[a] (total number of food-eating occasions = 46, 473)	Number of children[b] (total number of food-eating occasions = 72, 024)
1	1439 (3.1%)	2745 (3.8%)
2	1139 (2.5%)	312 (0.4%)
3	186 (0.4%)	254 (0.35%)
4	97 (0.2%)	83 (0.12%)
5	8 (0.02%)	56 (0.08%)
6	9 (0.02%)	0 (0%)
7	0 (0%)	0 (0%)

Notes: [a]National Teenagers Food Survey (NTFS) (2005–2006), 13–17 years ($n = 441$). [b]National Children's Food Survey (NCFS) (2003–2004), 5–12 years ($n = 594$).

Occurrence per food group

To gain insight into the distribution of the target food additives per food group, the presence of the target additives was investigated per brand per food group according to the European Union Directives (Tables 3a, b and 4). Regarding food colours (Table 3a and b), 'Fine bakery wares' and 'Non-alcoholic-flavoured drinks' were the food groups that contained the most branded products consumed by both the teenagers and children. However, the food group 'Confectionary' recorded the most brands containing the target food colours for both the teenagers and children. A number of food groups consumed by the children and teenagers did not contain any of the seven target additives. Also, not all of the European Union Directive food groups were consumed in the NCFS or in the NTFS. The children consumed a total of 20 food groups out of the 36 compiled where the six target food colours were legally permitted. Of these 20 food groups, 13 did not contain any of the six target colours. The teenagers consumed 23 food groups out of the possible 36 food groups. Of these 23 food groups, 15 did not contain any of the six target food colours. Food groups, such as 'Jams, jellies, marmalade', 'Sauces and seasonings', and 'Soups (dehydrated, canned, stock cubes)' are examples of food groups regularly consumed by the children and teenagers, yet did not contain any of the six target colours.

A similar trend emerges when analysing the intake of Sodium Benzoate (E 211) (Table 4). The children consumed a total of 16 food groups out of a possible 34 food groups in which Sodium Benzoate is legally permitted. Of these 16 food groups, 13 did not contain Sodium Benzoate. The teenagers also consumed 16 food groups out of a possible 34. Of these, 12 food groups did not contain Sodium Benzoate. 'Non-alcoholic-flavoured drinks' and 'Non-heat-treated desserts' were the food groups that contained the most brands consumed by both the children and teenagers. However, while a considerable amount of the brands in the 'Non-alcoholic-flavoured drinks' group contained sodium benzoate (42% of brands consumed by teenagers and 40% consumed by children), no brand consumed by the children in the 'Non-heat-treated desserts' contained the additive. Food groups, such as 'Low-sugar jams, jellies', 'Emulsified sauces with fat content of >60%', and 'Liquid soups and broths' were regularly consumed by the children and teenagers, yet did not contain sodium benzoate. Therefore, the primary source of sodium benzoate for both children and teenagers was through the 'non-alcoholic-flavoured drinks' food group.

Exposure to the seven target food additives

Estimated mean daily, 5th and 97.5th percentile intakes of the target additives and comparison with the doses used in the Southampton study (additives in Mixes A and B) are presented in Table 5. In general, apart from Tartrazine, a higher proportion of children consumed the target food additives compared with teenagers. This may reflect a higher preference for coloured sweet confectionery in the younger age group. However, apart from Carmoisine, intake of the target additives were generally higher in teenagers, which partly reflects the difference in energy intakes between the two groups (8.3 MJ day^{-1} for teenagers versus 7.0 MJ day^{-1} for children). Among consumers of any food colour, estimated mean intakes fell below the doses used in both mixes. Also, when higher intakes were examined (i.e. at the 97.5th percentile of food additive intake), values for both children and teenagers were less than those used in Mix B. In the case of Mix A, estimated intakes at the 97.5th percentile were lower for four food colours: Tartrazine, Ponceau 4R, Allura Red and Quinoline Yellow. In the case of the preservative Sodium Benzoate, the estimated 97.5th percentile of intake for both children and teenagers exceeded the dose used in both mixes.

Table 2. Frequency of meal-eating occasions containing one or more target additives in 594 children (aged 5–12 years) and 441 teenagers (aged 13–17 years).

Additive containing foods within a meal		Total number of meal-eating occasions	Number with one additive	Number with two additives	Number with three additives	Number with four additives	Number with five additives	Number with six additives	Number with seven additives
One food[a]	Teenagers	1307	1045	162	83	8	9	0	0
	Children	2867	2340	248	192	58	38	0	0
Two foods[a]	Teenagers	59	4	29	10	15	1	0	0
	Children	249	46	92	45	38	18	10	0
Three foods[a]	Teenagers	4	2	1	0	0	1	0	0
	Children	30	4	4	11	3	5	2	1
More than three foods[a]	Teenagers	1	1	0	0	0	0	0	0
	Children	5	1	0	0	3	1	0	0
Total meals with more than one additive-containing food	Teenagers	1371	1052	192	93	23	11	0	0
	Children	3160	2391	344	248	102	62	12	1

Note: [a]Number of foods within a given meal.

Table 3a. Brands per food groups and the occurrence of the target colours within these branded food items: teenagers.

Food group	Intake ($g\,day^{-1}$)	Number of brands	E110		E122		E102		E124		E129		E104	
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Americano	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Bitter soda	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Jams, jellies, marmalade	2.18	73	–	–	–	–	–	–	–	–	–	–	–	–
Luncheon meat	0.33	10	–	–	–	–	–	–	–	–	1	10	–	–
Chorizo sausage	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Breakfast sausage	9.52	88	–	–	–	–	–	–	–	–	–	–	–	–
Sobrasda	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Non-alcoholic flavoured drinks	228.27	253	–	–	4	1.58	2	0.7			2	0.7	1	0.3
Candied fruit and vegetables	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Preserves of red fruit	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Confectionary (sugar confectionary)	7.3	166	18	10.8	12	7.2	1	0.6	19	11.4	24	14.4	24	14.4
Decorations and coatings	5.93	122	1	0.8	2	1.6	–	–	4	3.2	6	4.9	1	0.8
Fine bakery wares	18.16	264	–	–	–	–	–	–	3	1.1	1	0.3	–	–
Edible ices	1.61	28	–	–	–	–	–	–	–	–	–	–	–	–
Flavoured processed cheese	0.005	1	–	–	–	–	–	–	–	–	–	–	–	–
Desserts including flavoured milk products	16.5	207	1	0.4	2	0.9	–	–	–	–	1	0.4	1	0.4
Sauces and seasonings	14.18	204	–	–	–	–	–	–	–	–	–	–	–	–
Mustard	0.03	9	–	–	–	–	–	–	–	–	–	–	–	–
Fish paste	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Pre-cooked crustaceans	0.34	9	–	–	–	–	–	–	–	–	–	–	–	–
Salmon substitutes	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Surimi	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Fish roe	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Smoked fish	0.29	7	–	–	–	–	–	–	–	–	–	–	–	–
Snacks	12.43	189	–	–	–	–	–	–	–	–	–	–	–	–
Edible cheese rind and casings	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Weight control formulae	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Complete nutritional supplements	0.32	1	–	–	–	–	–	–	–	–	–	–	–	–
Liquid food supplements, dietary integrators	1.38	14	–	–	–	–	–	–	–	–	–	–	–	–
Solid food supplements, dietary integrators	1.12	68	1	1.4	–	–	–	–	–	–	1	1.4	–	–
Soups (dehydrated, canned, stock cubes)	18.99	73	–	–	–	–	–	–	–	–	–	–	–	–
Meat and fish analogues based on vegetable protein	0.43	6	–	–	–	–	–	–	–	–	–	–	–	–
Spiritous beverages	3.6	2	–	–	–	–	–	–	–	–	–	–	–	–
Aromatized wines	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Fruit wines (cider, perry aromotized fruit wines, cider, perry)	3.37	1	–	–	–	–	–	–	–	–	–	–	–	–
Processed mushy and garden peas, canned	5.73	28	–	–	–	–	12	42.8	–	–	–	–	–	–

Notes: E110 = Sunset Yellow; E122 = Carmoisine; E102 = Tartrazine; E124 = Ponceau 4R; E129 = Allura Red; and E104 = Quinoline Yellow.
–, Not present.

Table 3b. Brands per food groups and the occurrence of the target colours within these branded food items: children.

Food group	Intake (g day^{-1})	Number of brands	E110		E122		E102		E124		E129		E104	
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Americano	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Bitter soda	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Jams, jellies, marmalade	1.34	90	–	–	–	–	–	–	–	–	–	–	–	–
Luncheon meat	1.25	25	–	–	–	–	–	–	–	–	–	–	–	–
Chorizo sausage	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Breakfast sausage	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Sobrasda	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Non-alcoholic flavoured drinks	187.46	339	6	1.7	3	0.8	–	–	2	0.5	2	0.5	1	0.2
Candied fruit and vegetables	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Preserves of red fruit	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Confectionary (sugar confectionary)	10.65	247	38	15.3	21	8.5	2	0.8	57	23	32	12.9	31	12.5
Decorations and coatings	3.75	16	–	–	–	–	–	–	–	–	–	–	–	–
Fine bakery wares	21.06	362	1	0.2	–	–	–	–	–	–	4	1.1	1	0.2
Edible ices	3.55	38	7	18.4	–	–	–	–	1	2.6			7	18.4
Flavoured processed cheese	0.07	3	–	–	–	–	–	–	–	–	–	–	–	–
Desserts including flavoured milk products	29.05	228		1	0.4	2	0.8		1	0.4	2	0.8	2	0.8
Sauces and seasonings	4.95	148	–	–	–	–	–	–	–	–	–	–	–	–
Mustard	0.01	5	–	–	–	–	–	–	–	–	–	–	–	–
Fish paste	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Pre cooked crustaceans	0.26	8	–	–	–	–	–	–	–	–	–	–	–	–
Salmon substitutes	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Surimi	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Fish roe	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Smoked fish	0.22	11	–	–	–	–	–	–	–	–	–	–	–	–
Snacks	12.47	203	1	0.4	–	–	–	–	–	–	–	–	–	–
Edible cheese rind and casings	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Weight control formulae	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Complete nutritional supplements	0.15	1	–	–	–	–	–	–	–	–	–	–	–	–
Liquid food supplements, dietary integrators	1	15	–	–	–	–	–	–	–	–	–	–	–	–
Solid food supplements, dietary integrators	17.46	51	–	–	–	–	–	–	–	–	–	–	–	–
Soups(dehydrated, canned, stock cubes)	12.22	108	–	–	–	–	–	–	–	–	–	–	–	–
Meat and fish analogues based on vegetable protein	0.33	7	–	–	–	–	–	–	–	–	–	–	–	–
Spiritous beverages	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Aromatized wines	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Fruit wines (cider, perry aromotized fruit wines, cider, perry)	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Processed mushy and garden peas, canned	3.84	44	–	–	–	–	17	38.6	–	–	–	–	–	–

Notes: E110 = Sunset Yellow; E122 = Carmoisine; E102 = Tartrazine; E124 = Ponceau 4R; E129 = Allura Red; and E104 = Quinoline Yellow.
–, Not present.

Table 4. Brands per food groups and the occurrence of sodium benzoate within these branded food items.

	Teenagers			Children		
	Intake ($g\,day^{-1}$)	*n* (Total)	*n* (E211)	Intake ($g\,day^{-1}$)	*n* (Total)	*n* (E211)
Non-alcoholic-flavoured drinks	231.51	232	97	184.37	332	130
Liquid tea concentrate and liquid fruit infusion concentrate	0	0	–	0	0	–
Grape juice	0	0	–	0	0	–
Saft	0	0	–	0	0	–
Alcohol-free beer in a keg	0	0	–	0	0	–
Spirits with less than 15% alcohol	3.59	4	2	0	0	–
Low-sugar jams, jellies	0	0	–	0.12	7	–
Candies, glace fruit and vegetables	0	0	–	0	0	–
Frugtgrod	0	0	–	0	0	–
Vegetables in vinegar, brine, oil	0.09	4	–	0.17	5	–
Olives and preparations	0.2	4	–	0.002	2	–
Fish roe, etc.	0	0	–	0	0	–
Salted, dried fish	0	0	–	0.02	2	–
Crangon	0	0	–	0	0	–
Non-heated dairy-based desserts	26.12	359	2	39.6	304	–
Liquid egg	0	0	–	0	0	–
Emulsified sauces, fat content of 60	2.99	61	–	0.68	36	–
Emulsified sauces, fat content of less than 60	0	0	–	0.001	1	–
Non-emulsified sauces	26.35	191	1	7.38	219	1
Prepared salad	2.4	2	–	0.19	8	–
Mustard	0.03	9	–	0.01	5	–
Seasoning and condiments	0.36	1	–	0.02	11	–
Liquid soups, broths	6.84	13	–	3.02	15	1
Aspic	0	0	–	0	0	–
Dietary food medical purpose	0.32	1	–	0	0	–
Mehu and makeutettu	0	0	–	0	0	–
Dulce de membrillo	0	0	–	0	0	–
Marmalade	0	0	–	0	0	–
Cooked red beet	0	0	–	0	0	–
Flavourings	0	0	–	0	0	–
Crustaceans and molluscs cooked	0.35	8	–	0.23	7	–
Food supplements supplied in liquid form	1.38	13	–	1	14	–
Chewing gum	0.64	21	–	0.27	28	–
Confectionary (non-chocolate)	6.72	157	–	9.69	293	–

Notes: E211 = sodium benzoate.
–, Not present.

In some cases of food additive intake, it was possible that certain individual children or teenagers may have had intakes greater than the doses used in either mix. For Mix B, no individual child or teenager had an estimated daily intake that reached the doses used for any additive except for Quinoline Yellow ($n = 4$) and Sodium Benzoate ($n = 53$). In the case of Mix A, the total number of individuals with estimated intakes exceeding the dose used were 15 for Sunset Yellow, 22 for Carmoisine, and 53 for Sodium Benzoate (Table 5). In all cases, there was no child or teenager who ever achieved an intake, even at the 97.5th percentile, on all seven days at the level used in the Southampton study.

Discussion

The results of the present study show that these conservative estimates of intake of food additives in Irish teenagers and children are below those used in the Southampton study which demonstrated a relationship between food additive intake and hyperactivity in UK children. The estimated upper intakes for a very small proportion of Irish teenagers and children exceeded the intake levels used in the Southampton study on individual days, but never on seven consecutive days. The estimated intakes of additives were made assuming that the additive was present at the maximum permitted level in those foods identified as containing them. It is a conservative assumption that is likely to result in significant overestimation of intakes. This is borne out by a recent study in Australia which found that the measured concentrations of added colours in foods are mostly less than 25% of the maximum permitted levels (Food Standards Australia New Zealand 2008).

When analysing the food groups permitted to contain the target food additives, it is clear that even

Table 5. Mean daily, 5th and 97.5th percentile intakes of the target food additives in consumers only for children and teenagers in all foods consumed compared with the doses present in Mixes A and B used by McCann et al. (2007), plus an indication of the number of children and teenagers who had intakes that exceeded these doses.

		Intake among consumers only (mg day^{-1})					Daily doses in the mixes used by McCann et al. and the number of subjects exceeding the doses			
					Percentile					
Food additive	Population	Percentage consumers	Mean	(SD)	5th	97.5th	Mix A (mg day^{-1})	Mix B (mg day^{-1})	Mix A, $n>$ dose	Mix B, $n>$ dose
Sunset Yellow	Children[a]	34.9	1.29	(2.1)	0.06	6.96	6.25	15.6	6	0
(E110)	Teenagers[b]	22.0	2.42	(2.9)	0.11	10.40			9	0
Carmoisine	Children	31.7	0.98	(1.7)	0.07	5.87	3.12	15.6	18	0
(E122)	Teenagers	14.3	0.59	(1.0)	0.11	3.57			4	0
Tartrazine	Children	13.3	1.28	(1.0)	0.24	3.81	9.36	0	0	0
(E102)	Teenagers	13.4	1.78	(1.5)	0.57	6.38			0	0
Ponceau 4R	Children	34.0	0.39	(0.5)	0.04	1.54	6.25	0	0	n.a.
(E124)	Teenagers	19.7	0.61	(0.9)	0.03	3.57			0	n.a.
Allura Red	Children	24.1	2.26	(2.0)	0.3	7.21	0	15.6	n.a.	0
(E129)	Teenagers	20.2	2.17	(2.1)	0.03	8.22			n.a.	0
Quinoline Yellow	Children	35.0	2.77	(3.3)	0.37	10.39	0	15.6	n.a.	3
(E104)	Teenagers	20.4	2.65	(3.0)	0.2	11.18			n.a.	1
Sodium Benzoate	Children	74.1	14.89	(15.8)	0.66	56.22	45	45	21	21
(E211)	Teenagers	64.4	22.14	(23.2)	2.83	76.79			32	32

Notes: n.a., Non-applicable as the additive not was present in the mix in the study of McCann et al. (2007); SD, standard deviation.
[a]Children, $n=594$.
[b]Teenagers, $n=441$.

though the food additives were permitted in a number of food groups, the children and teenagers only consumed a small proportion of these food groups (approximately half). Further to this, although the additives were permitted in these food groups, the majority of the brands consumed did not contain any of the target additives. This was also a contributory factor to the low exposure of the children and teenagers to the seven target additives.

The basis for selection of the intake levels of food additives in the Southampton study is not well established. The authors of that study state that the levels of additives used in Mix A were based on a previous study, while those of Mix B were 'selected to indicate the current average daily consumption of food additives by 3-year-old and 8–9-year-old children in the UK'. The reference cited to support this statement refers to a national survey of food intake in UK children (Gregory et al. 1995). This report gives details of the intake of intense sweeteners, but gives no data on the intake of any of the additives used in Mix A or B. Moreover, there are no published data available in the literature on the intakes of these additives by UK children. The authors also state that the challenge in their study was 'with quantities of additives equal to typical dietary intakes'. The results of the present study show that these doses are higher than even the highest exposures of Irish children and teenagers to the target additives. The intakes of food additives in Irish children are likely to be representative of those children in the UK since food-consumption patterns for Irish children are comparable with those reported in the UK (Gregory and Lowe 2000). For example, the pattern of food intake for four food categories associated with the use of food colours (biscuits, chocolate confectionary, non-chocolate confectionary and savoury snacks) is comparable between British and Irish children (respectively, 70 and 66 g day^{-1} for intake of the four food groups combined). Furthermore, although the food ingredient database used in the present study is regularly updated, the usage pattern adopted for the present study was that which prevailed in the retail market at the time of the Southampton study.

The published paper of the Southampton study refers to the two doses of additives used in terms of the intakes that would be expected from the consumption of multiple 56 g bags of sweets. In the case of Mix B, which was stated to equal normal exposure to the target food additives in UK children; this translates into two 56 g bags of sweets per day for the 3-year-olds and four such bags for the 8–9-year-olds. In the case of the latter, based on the energy value of an international brand of coloured sweets, this is equivalent to approximately 900 kcal day^{-1}, and this corresponds to 53% of the average daily energy intake of UK children aged 7/10 years. However, published data on the dietary habits of British children (Gregory and Lowe 2000) reveal that the average contribution of all sources of sugar confectionary to energy intake was just 7–9%.

In the present study, even more conservative deterministic estimates of food additive intakes were also computed (i.e. assuming that if an additive can legally be present in a food category, it will always be present; data not shown). The estimated mean intakes of all of the food colours used were also found to be below those purported to be typical among British children. This approach of conservatively calculating food additive intake was open to the regulatory agencies which reviewed that paper of McCann et al. (2007) based on publicly available data, but was evidently not pursued.

Conclusion

In Irish children and teenagers, levels of exposure to food additives rarely, if ever, reach the levels used in the Southampton study. In addition, the concurrent consumption of the combination of additives in either of the cocktails used in that study, in single foods or in eating occasions of multiple foods hardly ever occurs. These data would suggest that the risk-assessment process that followed from the Southampton study should be reconsidered.

Acknowledgements

This project was funded by the Irish Department of Agriculture, Food and Fisheries (DAFF) under the FIRM research programme (Grant no. 05/R&D/TCD/375).

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