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ASSESSING DIETARY RISKS CAUSED BY FOOD ADDITIVES: A CASE STUDY OF TOTAL DIET IN VIETNAM

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A risk assessment study of 6 types of food additives (including benzoates, sorbates, cyclamate, saccharin, tartrazine, and sunset yellow) in Vietnamese diets was conducted based on the food consumption research and food additives concentration followed by the guideline of World Health Organization. Surveys on food consumption and food sampling were conducted in 6 provinces including Ha Noi, Ho Chi Minh, Thua Thien Hue, Nam Dinh, Tay Ninh and Quang Tri. The survey results have determined the amount of food consumed for each different food product groups on different age groups. Test results of 6 food additives including benzoates, sorbates, saccharins, cyclamates, tartrazine and sunset yellow FCF using HPLC method show that benzoates and sorbates are the two most discovered groups of substances in the tested samples. The highest concentrations of these compounds were on jelly, soft drinks, ground meat, chilli sauce ... Types of food additives used as sweeteners are common in dried fruits, jam; the cyclamate content was very high in these two product groups. The colouring agents content were at a much lower level, mainly found in chili sauce. Risk assessment results show that total intake of sorbate and benzoate in the group of children under 5 years old were the highest value, which was 38 % of ADI. For all other age groups, the risk ranged from 10.6 to 34.0 % ADI for benzoates and from 0.56 to 1.8 % ADI for sorbates. For the remaining 4 food additives, total consumption was much lower than their ADIs. With the assumption that people used all types of food, 0.8 % of the population had the intake of benzoate exceed its ADI.

Food additives are commonly used worldwide. Many types of food additives have been accepted by Codex Alimentarius to be used in foods such as preservatives, sweeteners, coloring products, flavorings... [1]. In Vietnam, some commonly used food additives include benzoates, sorbates, cyclamate, saccharin, tartrazine, and sunset yellow. Although there are regulations on the maximum limits of these substances in many food categories, the total intake of these compounds maybe higher because there are many types of foods that contain the same compounds. According to previous investigations, there were a number of food additives in different food matrices, including sodium benzoate, potassium sorbate, sodium oxalate, sodium citrate, artificial sweeteners and coloring agents [2, 3]. The level of each food additive on each commodity were found within the regulatory limit, but people consume more than one types of food, then the total intake of food additives may exceed the safety level.

Risk assessment is a component of the process of risk analysis besides risk management and risk communication. The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) have published the principles of chemical risk assessment in food. JECFA, which is the FAO/WHO joint committee, is responsible for risk assessment for food additives. The risk assessment process is based on the general principles guided by the "Princi-

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ples and methods of chemical risk assessment in food" and consists of four main stages including hazard identification, hazard characterization and exposure assessment and risk characterization [4].

The first two steps ussually performed before approval of any food additive base on invitro and invivo studies in laboratory animal. The extent to which a food additive can pose a health risk depends upon its toxicity and the dietary exposure. JECFA establishes acceptable daily intake (ADI) values for food additives. ADI values are calculating using a safety factor which ensures that if the additive is consumed daily at that level for the rest of one's life, there would be no «appreciable health risk» [5]. According to the Codex Alimentarius reports and EFSA studies [6–11], the definition of food additives, their INS number and the acceptable daily intake (ADI) for each compound were shown in Table 1. Exposure assessment is the next step which requires the information of food additives consumption. Usually the 24-hour dietary recall survey or the food frequency questionnaire (FFQ) is the tool of choice for estimating the intake of foods likely to contain additives. Concentration of the additive in different foods is chemically estimated to ultimately calculate the dietary exposure to the additive. And finally, the probability of occurrence of adverse toxic effects in humans as a result of exposure to food additive is assessed. This is usually done by comparing ADI values of the additive with exposure levels among humans.

Many risk assessment studies have been published worldwide. According to Cressey and Jones study in New Zealand, mean population level estimates of dietary exposure were well below the respective acceptable daily intakes (ADIs) for all age-gender groups for all preservatives at 7–27%, 1–4% and 1–8% of the ADI for sulfites, sorbates and benzoates, respectively [12]. Another research of Bemrah et al. about the assessment of dietary exposure to 13 selected food colours, preservatives, antioxidants, stabilizers, emulsifiers and sweeteners in French population showed that the intake estimates are reassuring for the majority of additives studied since the risk of exceeding the ADI was low, except for nitrites, sulfites and annatto, whose ADIs were exceeded by either children or adult consumers or by both populations under the modelling assumptions [13]. Another study of Chung et al. in Korea for saccharin, stevioside, D-sorbitol and aspartame stated that the EDIs of artificial sweeteners

Table 1

The studied food additives with their definition and ADI values [6–11]

Food additives	Definition	INS number	ADI (mg/kg b.w.)
Benzoates	Acid benzoic Natri benzoate Kali benzoate Calci benzoate	210 211 212 213	0–5
Sorbates	Acid sorbic Kali sorbate Calci sorbate	200 202 203	0–25
Saccharin	Saccharin Calci saccharin Kali saccharin Natri saccharin	954(I) 954(II) 954(III) 954(IV)	0–5
Cyclamate	Acid cyclamic Calci cyclamate Natri cyclamate	952(I) 952(II) 952(III)	0–7
Tartrazine	Tartrazine	102	0–7,5
Sunset yellow FCF	Sunset yellow FCF	110	0–1

such as saccharin and aspartame in Korea are significantly lower than ADI set by the JECFA [14]. Then, Ha et al. assessed the consumer exposure to sodium saccharin, aspartame and stevioside and confirmed that for most Korean consumers, the EDIs were no greater than 20% of their corresponding ADI; however, the EDI of sodium saccharin for conservative consumers aged 1–2 years reached 60% of their ADI [15]. These authors also assessed the synthetic colours in Korea [16]. Rao et al. assessed intakes of synthetic food colours: tartrazine, sunset yellow and erythrosine in India to be 7.5, 2.5 and 0.1 mg/kg body weight, respectively [17]. Another research in India showed that Though sunset yellow FCF and tartrazine were the two most popular colours, many samples used a blend of two or more colours [18].

In Vietnam, risk assessment has been recently applied for the risk based control of chemicals and microorganism. Some risk assessments have been done for mycotoxins or heavy metals [19–21]. However, there has not been any risk assessment study of food additives. Therefore, assessing the total amount of chemical exposure based on the Vietnamese diet is an important parameter to study the impact of these chemicals on the health of Vietnamese people.

This study conducted a risk assessment of the 6 additives namely benzoates, sorbates, cyclamate, saccharin, tartrazine, and sunset yellow for Vietnamese health. The assessment includes steps according to FAO/WHO guidelines and is compared with acceptable daily intake (ADI) recommended by the Codex Alimentarius.

Materials and Methods

The study evaluated 6 groups of food additives (benzoates, sorbates, cyclamate, saccharin, tartrazine and sunset yellow FCF) in the food samples of the diet at risk of containing of food additives, including confectionery, soft drinks, processed meat products, jam, spices, canned food, instant cereals, instant coffee, dairy products, and supplements.

The food consumption study has been conducted in urban and rural areas in 6 provinces in the North, Central and South of Vietnam including Hanoi, Nam Dinh, Thua Thien Hue, Quang Tri, Ho Chi Minh and Tay Ninh. The respondents were divided into different age groups including young children (≤5 years), elementary students (6–10 years), high school students (11-18 years), adults (19–40 age) and middle/elderly people (> 40 years). The total number of households surveyed was 2700, which was calculated according to the sample size calculating formula. All participants were interviewed about their diet recall for 24 hours and for 1 week that related to the studied food group. They weight were also assessed by using a health scales (for young children) or by interviewing (for other age group).

The total number of food samples collected in the provinces was 2970 samples. Samples were analyzed at the ISO/IEC 17025:2017 accredited laboratory of National Institute for Food Control (NIFC) using HPLC methods.

The survey data on food consumption are collected by Epidata software 3.1. SPSS 16.0 software is used to evaluate food consumption statistics and test results of food additives.

Results and Discussion

General characteristics of the research object

Of the 2700 households interviewed, total 10499 people were assessed. The age group distribution and the average weight of the study subjects are presented in Table 2.

The age distribution of the research group and their average weight shows that the majority of the study population was adulthood

Table 2

Average weight by different age groups

Age groups	Frequency	Percentage	Weight	
			Average	SD
≤ 5	847	8.1	14.3	5.18
6–10	720	6.9	26.1	19.82
11–18	1051	10.0	43.7	11.53
19–40	3452	32.9	56.3	17.81
> 40	4429	42.2	56.7	13.91
TỔNG	10499	100.0	49.5	–

(over 18 years) accounts for more than 75%. The average weight of this group was about 56.5 kg, while the average weight of all subjects was 49.5 kg. These results are also consistent with the current convention that the average weight of Vietnamese people is 55 kg. In this study, the actual average weight of adults was taken from the actual data of 56.5 kg.

Determination of food additive content

Detection limit values of food additives according to ISO 17025 accredited method for benzoates, sorbates, saccharin, cyclamate, tartrazine, sunset yellow FCF are 10 mg/kg, 2 mg/kg, 40 mg/kg, 0.5 mg/kg and 0.5 mg/kg, respectively. In this study, as food additives are often added to foods with a fairly high content, for samples with not detected results, they were assessed to be zero.

Benzoates and sorbates are the two most common groups of food additives in tested samples. In particular, most notably on jelly, soft drinks, grind meat rolls, chili sauces. Types of sweeteners are common in dried fruits and jams. Especially, the cyclamate content is very high in these two product groups. The coloring agents were at much lower content, mainly in chili sauces.

Some groups of food products with low additive content such as instant noodles, instant cereals, instant coffees, instant teas, ice cream, yogurt, sausage, dried meats, roasted meats, canned meats, canned vegetables and fruits.

Table 3

The amount of food additives in different food groups (gram)

Food category	Sorbate	Benzoate	Saccharin	Cyclamate	Tartrazine	Sunset yellow FCF
Cake/pie	38.01	6.84	4.35	0	0.17	0.42
Candy	6.17	44.83	19.89	6.27	4.77	3.25
Jelly	256.2	124.1	7.43	21.67	2.22	2.45
Snack	149.2	74.04	14.38	71.33	2.38	1.44
Soft drinks	19.36	76.6	28.07	2.3	1.84	4.37
Fruit juices	7.62	45.74	13.88	4.86	0.29	1.92
Jam	26.78	64.57	30.39	170.4	0.83	2.91
Dried fruits	127.3	172.5	88.46	149.9	0.35	0.74
Dried grind meats	82.6	108.7	0	0	0	0
Grind meat rolls	163.8	287.6	0	0	0	0
Sausages	30.9	17.74	0	0	0	0
Roasted meats	23.25	16.21	0	0	0.07	0
Canned meats	0	4.66	0	0	0	0.08
Dried meats	2.3	25.03	3.41	0	0.83	4.26
Chili sauces	106.8	297.1	10.32	7.05	1.34	19.85
Soy sauces	71.2	201.8	15.84	0	0	1.07
Fish sauces	75.81	181.2	49.74	0	0	0
Instant noodles	0	9.2	0	0	0.76	0.42
Instant cereals	0	0.78	0.69	0.74	0.08	0.07
Instant coffees	0	0	24.54	0	0	0
Instant teas	0	2.13	2.54	0	0.08	0.09
Canned vegetables	12.46	31.1	7.33	6.34	0.04	0.01
Ice cream	0	0	0	0	0.13	0.44
Yogurt	0	2.37	2.91	0	0.46	0.53
Food supplements	10.83	26.17	5.79	0	5.09	8.21

Because many products were not detected with additives, the standard deviations of some cases were quite high. However, in the framework of this study, average results are used as data in risk assessment.

Evaluation of food consumption and the intake of food additives by food groups

Based on statistical survey data on food consumption, consumption characteristics of each food product by age group were evaluated. Among the food assessed, the beverage group is the food group that has individuals exceeding ADI for benzoate. However, for each food group and each type of additives, average consumption dose of these additives were lower than ADI. The data of soft drink group is shown in table 4 and table 5 as an example.

It can be seen that the rate of people using soft drink was quite high, the largest among the 11–18 year old teenagers (71.4%), but the average one-time use was highest in the 6–10 years old. Calculating for all age groups, average usage was about 400 g. This consumption was used to evaluate the intake dose by age group and is summarized in table 5.

The highest average intake was found for the benzoate group and in the group under 5 years old, which was 1.81 mg/kg b.w. For other food additives, the intake dose on soft drink is also higher than that of other food product groups.

Evaluation of the total intake of food additives in the total diet

With the hypothesis that is consumers use at least 1 food product to all types of food products on the same day, the total consumption of each food additive was evaluated and presented in table 6.

The results in table 5 show that the total intake of sorbate and benzoate is highest and in the group of children under 5 years old, which were 1.5 and 1.9 mg/kg b.w., respectively. These doses were still within the limits of ADI for both groups of these substances. For benzoates, the estimated daily intake (EDI) was from 10.6 to 38% of it corresponding ADI. This figure for sorbate was much lower, which were just 0.56% to 1.8% of ADI. For the remaining 4 food additives, total consumption is much lower than their ADI. The coloring group (tartrazine and sunset yellow) has the lowest consumption. In the sweetener group, the total consumption of saccharin is higher than that of cyclamate, but still 15–40 times lower than ADI depending on the age group.

The number of total consumption of food additives for each individual which is higher than the ADI is also evaluated, and presented in Table 7.

With the above hypothesis, the number of people with total intake of higher than benzoate's ADI accounts for the highest percentage, especially in low age groups. In the group of less than 5 years of age and the group of 6–10 years, there were 4.6% and 2.6% exceeding ADI, respectively. On average, about 0.8% of people assessed have total consumption exceeding ADI for benzoates.

In addition, there are a few other individuals whose total intake of sorbate, saccharin and sunset yellow exceeds ADI, and they are also concentrated in the lower age group. The risk for these compounds is negligible.

Table 4

Soft drink consumption by age group

Age group	Total	Number of people used		Intake (g/day)			
		n	%	Average	SD	Min	Max
≤ 5 years old	695	248	35.7	337.2	229.84	25	1500
6–10 years old	626	347	55.4	429.5	488.99	250	6000
11–18 years old	788	563	71.4	381.7	260.37	250	4500
19–40 years old	1965	1161	59.1	407.2	316.61	250	6000
> 40 years old	2259	989	43.8	411.6	297.44	250	3000
Total	6333	3308	52.2	401.3	320.28	25	6000

Table 5

Intake of food additive by age group (mg/kg b.w.) when consuming soft drink

Age group	Food additives	N	Average	SD	Min	Max
≤ 5 years old	Sorbate	248	0,456568	0,311178	0,033850	2,030770
	Benzoate	248	**1,806463**	1,231212	0,133920	8,034970
	Saccharin	248	0,661977	0,451176	0,049070	2,944410
	Cyclamate	248	0,054241	0,036968	0,004020	0,241260
	Tartrazine	248	0,043393	0,029575	0,003220	0,193010
	Sunset yellow FCF	248	0,103058	0,070240	0,007640	0,458390
6–10 years old	Sorbate	347	0,318595	0,362717	0,185440	4,450570
	Benzoate	347	**1,260555**	1,435130	0,733720	17,609200
	Saccharin	347	0,461929	0,525902	0,268870	6,452870
	Cyclamate	347	0,037850	0,043091	0,022030	0,528740
	Tartrazine	347	0,030280	0,034473	0,017620	0,422990
	Sunset yellow FCF	347	0,071914	0,081874	0,041860	1,004600
11–18 years old	Sorbate	563	0,169111	0,115353	0,110760	1,993590
	Benzoate	563	**0,669107**	0,456406	0,438220	7,887870
	Saccharin	563	0,245194	0,167249	0,160580	2,890500
	Cyclamate	563	0,020091	0,013704	0,013160	0,236840
	Tartrazine	563	0,016073	0,010963	0,010530	0,189470
	Sunset yellow FCF	563	0,038172	0,026038	0,025000	0,450000
19–40 years old	Sorbate	1161	0,140013	0,108876	0,085970	2,063230
	Benzoate	1161	**0,553978**	0,430780	0,340140	8,163410
	Saccharin	1161	0,203005	0,157859	0,124640	2,991470
	Cyclamate	1161	0,016634	0,012935	0,010210	0,245120
	Tartrazine	1161	0,013307	0,010348	0,008170	0,196090
	Sunset yellow FCF	1161	0,031604	0,024576	0,019400	0,465720
> 40 years old	Sorbate	989	0,140532	0,101561	0,085360	1,024340
	Benzoate	989	**0,556029**	0,401839	0,337740	4,052910
	Saccharin	989	0,203756	0,147253	0,123770	1,485190
	Cyclamate	989	0,016695	0,012066	0,010140	0,121690
	Tartrazine	989	0,013356	0,009653	0,008110	0,097350
	Sunset yellow FCF	989	0,031721	0,022925	0,019270	0,231220

Table 6

Total intake of food additives of age groups (mg/kg b.w.)

Age group	Food additives	N	Average	SD	Min	Max
≤ 5 years old	Sorbate	764	**1,548362**	2,160869	0,000000	36,947490
	Benzoate	764	**1,886320**	1,947033	0,000000	21,280590
	Saccharin	764	0,330762	0,483127	0,000000	3,420870
	Cyclamate	764	0,177728	0,241519	0,000000	3,265000
	Tartrazine	764	0,029699	0,038514	0,000000	0,392030
	Sunset yellow FCF	764	0,055880	0,079646	0,000000	0,568370
6–10 years old	Sorbate	645	**1,246741**	1,326715	0,002490	20,205960
	Benzoate	645	**1,711453**	1,702170	0,005500	24,146250
	Saccharin	645	0,348452	0,501063	0,000000	7,567360

Age group	Food additives	N	Average	SD	Min	Max
	Cyclamate	645	0,150885	0,164616	0,000000	1,788870
	Tartrazine	645	0,028883	0,035141	0,000000	0,549210
	Sunset yellow FCF	645	0,057721	0,079524	0,000000	1,220920
11–18 years old	Sorbate	813	0,763875	0,640765	0,000000	5,181750
	Benzoate	813	**1,222627**	0,822839	0,000000	7,933700
	Saccharin	813	0,234662	0,202015	0,000000	2,908430
	Cyclamate	813	0,085542	0,081287	0,000000	0,647320
	Tartrazine	813	0,017807	0,013804	0,000000	0,194340
	Sunset yellow FCF	813	0,038611	0,032411	0,000000	0,453840
19–40 years old	Sorbate	2551	0,411440	0,373940	0,000000	4,182480
	Benzoate	2551	0,771790	0,640250	0,003870	10,731790
	Saccharin	2551	0,131729	0,176981	0,000000	3,751350
	Cyclamate	2551	0,037838	0,057337	0,000000	0,504090
	Tartrazine	2551	0,008916	0,011403	0,000000	0,214140
	Sunset yellow FCF	2551	0,021114	0,028083	0,000000	0,576460
> 40 years old	Sorbate	2228	0,272799	0,366641	0,000000	6,053790
	Benzoate	2228	0,538597	0,579170	0,000000	6,313950
	Saccharin	2228	0,127510	0,162306	0,000000	1,512330
	Cyclamate	2228	0,040153	0,057071	0,000000	0,683800
	Tartrazine	2228	0,008904	0,010481	0,000000	0,100320
	Sunset yellow FCF	2228	0,020258	0,025695	0,000000	0,234780

Table 7

The number and proportion of consumers with total intake of food additives exceeding ADI with the above hypothesis

Age group	Sorbates		Benzoates		Saccharin		Cyclamate		Tartrazine		Sunset yellow FCF	
	n	%	n	%	n	%	n	%	n	%	n	%
≤ 5 years old	1	0.1	35	4.6	–	–	–	–	–	–	–	–
6–10 years old	–	–	17	2.6	2	0.3	–	–	–	–	2	0.3
11–18 years old	–	–	3	0.4	–	–	–	–	–	–	–	–
19–40 years old	–	–	2	0.1	–	–	–	–	–	–	–	–
> 40 years old	–	–	2	0.1	–	–	–	–	–	–	–	–
Total	1	0.01	59	0.8	2	0.03	–	–	–	–	2	0.03

No individual had a total intake of cyclamate and tartrazine exceeding ADI, indicating a very low risk for both groups of these food additives.

Conclusion

The first total diet study was conducted in the study of dietary risk assessment of 6 food additives. The data showed that the average food additive intakes of consumer in Vietnam were within the recommendation of Codex Alimentarius. This study is a recommendation to a better food additives management and communication.

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