Bisphenol A in canned fruit and vegetable in Tehran, Iran: a health risk assessment Study

Reza Hazrati-Raziabad
Tehran University of Medical Sciences
Ramin Aslani
Tehran University of Medical Sciences
Nabi Shariatifar
nshariatifar@ut.ac.ir
Tehran University of Medical Sciences
Majid Arabameri
Ministry of Health and Medical Education
Parisa Sadighara
Tehran University of Medical Sciences
Gholamreza Jahed Khaniki
Tehran University of Medical Sciences

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Abstract

This study aimed to investigate bisphenol A (BPA) contents in canned fruit and vegetable samples using Gas Chromatography-Mass Spectrometry (GC-MS). The mean concentration of BPA in canned samples of lentils, apricots, cherries, pineapples, eggplant stew and green peas was 21.87, 4.52, 3.92, 1.86, 1.67 and 1.62 μg/kg, respectively. The level of BPA in the samples was within the standard level. The pH value in canned fruits varied from 3.6 to 4.7 (mean = 4.15) and in canned vegetables from 4.3 to 5.9 (mean = 5.21). The mean sugar content was 41.42% (range 38–48%) and the mean fat value was 24.234% (ranged 24.7–48%). Furthermore, health risks were assessed for Iranian adults, and children. The 95th percentile ADI values of BPA in canned fruit for adults and children were 6.12E-08, and 2.16E-07 mg/kg bw/day; and in canned vegetables were 1.78E-07, and 6.26E-07 mg/kg bw/day, respectively. The 95th percentile THQ values in canned fruit for adults and children were 1.48E-06, and5.24E-06; and in canned vegetable were 3.56E-06, and 1.27E-05, respectively and HQ was less than 1. The results show that exposure to BPA through the intake of this samples does not pose a serious risk to human health.

1. Introduction

Canned foods refer to products that undergo a canning process, including pretreatment, filling, sealing, and sterilizing the can. In fact, canning is a food preservation method, especially for perishable foods such as vegetables, fruits, and meat [1,2]. Canned products provide valuable nutrients such as carbohydrates, vitamins, proteins and minerals. Despite the significant advantages of various packaging techniques, contact between food and packaging materials can cause chemical reactions and leakage of packaging material compounds into the food [3,4]. The inner coating of metal cans is made using epoxy resins (polymer coating) to prevent unwanted contact and reactions between the inner surface of the cans and food, and as a result, erosion and rust are prevented [5,6].

Since the 1960s, bisphenol A [2,2-bis(4-hydroxyphenyl)propane; BPA] has been widely utilized in the manufacturing of polycarbonate plastics, epoxy resins and stabilizer agent in polyvinyl chloride [7]. BPA is an artificial organic substance (generated by blending phenol and acetone) featuring two phenolic rings linked via a variously substituted carbon atom and also has two methyl functional groups [8]. BPA migration process is usually physical and chemical. Physical migration occurs due to the release of residual BPA after the manufacturing process, while chemical migration occurs when BPA is released from the polymer surface as a result of hydrolysis[9]. BPA primarily leaches into canned food under acidic conditions, during high-temperature processing, and from incompletely polymerized epoxy resins [6,8].

There is scientific evidence that BPA acts as an endocrine-disrupting exogenous chemical capable of altering hormones, mimicking the action of the hormone estrogen, and causing significant adverse effects on reproductive abilities. The ability of BPA to mimic estrogen is related to its hydroxyl groups in the para position [10]. Moreover, some research has shown that BPA exposure may increase the risk of certain diseases, including, obesity, autism, diminished antioxidant enzymes, cardiovascular diseases, metabolic disorders, and cancers [11,12].

BPA is detected across various environmental media and both dietary and non-dietary exposure to BPA is possible. Nevertheless, the most common pathway of its exposure is the ingestion of food, which poses major hazards to vulnerable populations such as children and the elderly [13]. Public concerns and government regulations have motivated the development and manufacture of alternative materials to BPA, for example, BPS, BPF, BPB, and BPAF have been utilized as substitutes for polycarbonate plastic or resin.

Currently, BPA is one of the most common xenoestrogens studied in food samples. However, there have been cases where other analog compounds have been found in higher amounts, indicating that manufacturing companies are gradually replacing BPA with other bisphenols in food packaging [3,14,15]. Nevertheless, it is worth mentioning that BPF and BPS have demonstrated estrogenic and/or antiandrogenic properties that are comparable to or even greater than those of BPA [16]. BPA attracts considerable attention because of its adverse health effects, its presence in a diverse range of food products, and its pervasive occurrence in the environment [7].

The EU Commission has fixed a maximum migration limit of 600 μg/kg for BPA in food products [17]. The maximum permissible concentration and the tolerable daily intake (TDI) of BPA were set at 50 μg/kg bw/day by the U.S. EPA [18] and the EFSA [19], respectively. Also, Health Canada recommended the provisional TDI of BPA at 25 μg/kg bw/day [20].

Bisphenol analysis is often carried out by employing chromatographic techniques, such as Gas chromatography/mass spectrometry (GC-MS) [6], ultra-performance liquid chromatography-mass spectrometry (UPLC-MS/MS) [21], and high-performance liquid chromatography (HPLC) [22].

The presence of BPA in canned fruits and vegetables has been numerously documented worldwide, including Belgian [7], Korea [3,22], Canada [23], China [24], the United States [25–27], and France [28]. However, information on BPA content in canned fruit and vegetables sold in Iran is not available, and on the other hand, consumption of these canned foods is high in Iran and the world. Thus, the present study aimed to (1) investigate BPA levels in some canned fruits and vegetables in Tehran, Iran, (2) evaluate some variables in canned fruits and vegetables concerning the BPA concentration, including the pH and the contents of fat and sugar, and (3) assess the health risks associated with exposure to BPA from the consumption of canned fruits and vegetables.

2. Materials and Methods

2.1. Reagents

All chemicals were of analytical grade. BPA was supplied from Sigma-Aldrich (West Chester, PA; USA). Acetonitrile, n-hexane, magnesium sulfate, sulfuric acid, sodium chloride (NaCl), methylene blue, fehling's solution, potassium carbonate, sucrose, acetic anhydride, tetrachloroethylene, and isoamyl alcohol were purchased from Merck Co., (Darmstadt, Germany).

2.2. Sample Collection

In total, 96 samples including canned fruit (cherry, pineapple, and apricot) and canned vegetables (eggplant Stew, lentils, and green peas) were gathered from supermarkets in Tehran, Iran. All samples were canned in metal containers and were divided into two groups based on their production time: less than 6 months and more than 6 months. These two groups were stored in two different conditions: environment temperature and refrigerator temperature. Subsequently, the samples were labeled and transferred to the laboratory and kept at -18 °C until further analysis.

2.3. Bisphenol A measurement

2.3.1. Sample Preparation and Derivatization

Initially, 2 g of the homogenized canned fruit and vegetable samples were added to 5 mL of acetonitrile and vortexed for 1 min, then 4 mL n-hexane was added and vortexed for 2 min. The mixture was ultrasonicated for 20 min with 4 cycles of 5 min each. Then, it was centrifuged at 3500 rev/s for 5 min and the n-hexane layer was removed. Finally, the mixture was filtered using folded filter paper, and then 4 mL n-hexane was added. The obtained mixture was transported to a vial, and 50 μL of MSTFA derivatives were added to it. The vial was put in an oven at 50°C for 1 h, then it was injected into the GC-MS.

2.3.2. Sample Analysis

The analysis of samples was carried out using Gas Chromatography (Agilent 7890, Palo Alto, CA, USA) with a mass spectrometric detector (Agilent 5975), and equipped with a capillary column (HP5-MS; Column length: 30 m; internal diameter: 0.25 mm; film thickness: 0.25 μm). The GC-MS operating conditions were: the gas of carrier: helium (99.999%); rate of flow: 1 mL per minute; the mode of injection: splitless; the volume of injection: 2 μL. Ultimately, the SIM (selected ion monitoring) mode was utilized for the detector.

The correlation coefficient (R^2) of the curve was 0.991. The detection limits (LOD) and detection quantifications (LOQ) for bisphenol A were 0.1 and 0.35 ng/g, respectively. The relative standard deviation (RSD) was 8.9% and the recovery rate was 99.8%.

2.4. Fat measurement

The fat content in the sample was measured according to the AACC method 30 – 10. First, samples were dried at 105°C. Then, 4 g of dried sample was accurately weighed, placed onto a filter paper, and wrapped, then transported to a Soxhlet extractor with a flask containing n-hexane. The sample was extracted constantly for 3 h at 70°C. The samples were put in an oven at 100°C on rotary and then transferred to a desiccator until cooled down. The fat content was measured by weighing [29,30].

2.5. Sugar measurement

First, 25 g of sample with 6–10 mL of hydrochloric acid was added to a 100 mL volumetric flask and it was placed in a water bath for 10 min at 70 ^{O}C. Then, the volumetric flask was cooled, a few drops of phenolphthalein were added to it and it was neutralized with 40% sodium hydroxide and 0.1 N sodium hydroxide to create a stable light pink color. Next, 5 mL of Fehling solution A and 5 mL of Fehling solution B were poured into the Erlenmeyer flask and mixed, also a few glass balls, 3 to 4 drops of methylene blue and about 20 mL distilled water were added to the Erlenmeyer flask to avoid quick evaporation. The obtained solution was heated on a hot plate until it boiled for 2 min. Then was poured the neutralized solution into the burette and while boiling Fehling's solution, slowly added the neutralized solution to the Erlenmeyer until it turned the brownish-red color of Cu_2O. The consumption volume of the solution was recorded [31].

$$\mathrm{N} = \frac{\mathrm{F} \times 100 \times 100 \times 100}{\mathrm{V} \times 25 \times 25}$$

Where F is the Fehling factor; V is the volume of solution consumed in mL, and N is total sugars (sugar after hydrolysis) in grams per % gram.

2.6. pH measurement

For this purpose, 10 g of sample was added to 100 mL distilled water, then the pH of the mixture was examined utilizing an electronic pH meter (Hach, USA) [31].

2.7. Risk Assessment

To the estimation health risk of BPA in canned fruit and vegetables, the average daily intake (ADI), and target hazard quotient (THQ) were used and calculated by the following equations[32]:

$$ADI = \frac{C \times ED \times EF \times IR}{BW \times AT}$$

1

$$\mathrm{THQ} = \mathrm{ADI} \;/\; \mathrm{RfD}$$

2

Where C is the concentration of BPA in samples (µg/kg), IR is the canned fruit and vegetables ingestion rate (1 g/person/day), the oral reference doses for Bisphenol A was 0.05 (µg/kg - day) [33]., ED (exposure duration, years), EF (exposure frequency, days/year)[34], BW is body weight (70 kg for adults, and 20 kg for children), AT (AT is the mean time (25550 days)([35] and RfD is the oral reference dose of BPA (50 μg/kg/day). Additionally, the 95th percentile risk values were provided to highlight notable risks [36]. A Monte Carlo simulation (Oracle@ Crystal Ball, Oracle Corporation, USA) was applied to conduct the uncertainty analysis. The AAD values were compared to the fixed tolerable daily intake (TDI) of BPA which was recommended by the EFSA at 4 μg/kg bw/day [37].

2.8. Statistical Analysis

The data were analyzed using IBM SPSS Statistics version 22. The Kolmogorov–Smirnov test was used to determine the distribution of the study parameters. The results were evaluated by the Spearman Correlation. The significance level was considered $p < 0.05$. The Kruskal–Wallis test was applied to determine the significance between groups. The principal component analysis is a multivariate technique and is widely used in food contamination with the aim to find out the associations between contaminants and food products [38,39]. The Monte Carlo simulation was executed using the Oracle Crystal Ball.

3. Results and Discussion

3.1. BPA concentrations in the canned fruit and vegetable samples

The concentrations of BPA in the selected canned fruit and vegetable samples with their corresponding sugar, fat, and pH values are presented in Table 1. BPA was detected in all samples (LOD = 0.1 μg/kg). The median concentration of BPA was 2.34 μg/kg and an average of 3.44 μg/kg. The concentration of BPA in the canned fruit ranged from 0.87 (cherry, > 6 months, at 4°C) to 9.70 μg/kg (cherry, < 6 months, at 25°C). The median concentration of BPA in canned vegetables was 2.04 μg/kg and an average of 8.38 μg/kg. The concentration of BPA in the canned vegetables ranged from 0.87 (green peas, > 6 months, at 4°C) to 28.35 μg/kg (lentils, > 6 months, at 25°C). Similarly to Cunha and Fernandes's study, the mean concentration of BFA in canned fruits was less than those in canned vegetables, which may linked to employing electrolytic tinplate in fruit containers instead of epoxy films [6]. As shown in Fig. 1, the descending order of mean concentration of BPA in studied samples was as follows: lentils (21.87 μg/kg) > apricot (4.52 μg/kg) > cherry (3.92 μg/kg) > pineapple (1.86 μg/kg) > eggplant stew (1.67 μg/kg) > green peas (1.62 μg/kg). All samples with a production time of more than 6 months had higher BPA levels when stored at 25°C compared to those kept at 4°C. All samples with a production time of more than 6 months had higher BPA levels when stored at 25°C compared to those kept at 4°C. The results have shown that the amount of BPA in all samples was within the maximum allowable concentrations. However, this does not guarantee that individuals not will be exposed to health hazards, so assessing the health risks of exposure to BPA is necessary. The results of the statistical analysis indicated that there was no significant difference between the contents of BPA, pH, % sugar, % fat, storage conditions, and production time among the different types of studied canned samples ($p > 0.005$).

In comparison, Geens et al. found a statistically significant correlation between the fat content of canned beverages and foods and the content of BPA ($p = 0.004$). The sugar contents in the canned fruits ranged from 38–48%, and the mean was 42.41%. The fat contents in the canned vegetables ranged from 24.7–48%, and the mean was 34.24%. The descending order of the mean of sugar in canned fruit samples was as follows: pineapple (47.5%) > apricot (41.5%) > cherry (38.2%), and the descending order of the mean of fat in canned vegetable samples was as follows: eggplant stew (45.87%) > lentils (31.90%) > green peas (24.95%). The pH value in the canned fruits ranged from 3.6–4.7 (mean = 4.15) and in the canned vegetables ranged from 4.3–5.9 (mean = 5.21). The increasing order of mean concentration of pH in studied samples was as follows: cherry (3.7) > pineapple (4.17) > eggplant stew (4.32) > apricot (4.6) > lentils (5.55) > green peas (5.77). Osman et al. reported pH in the canned fruit pH 3.2–3.8 (peach) and 2.3 (pickles lemon) – 6.6 (bean) [8]. As the pH increases, BPA migration into the food can accelerate because of hydrolysis of the packaging [40].

The concentration of BPA recorded in the present study compared with those reported in the previous literature are summarized in Table 2, including country, type, and number of samples analyzed, mean and range concentrations of BPA, and analytical method. BPA levels in canned fruits found in our study (0.87–9.7 µg/kg) were in line with those reported for canned fruit by Cunha and Fernandes (< 0.3–10.2 µg/kg) [6] and Geens et al. (< 0.02–8.1 µg/L) [7]. Our recorded amount of BPA in canned fruits was more than that reported by Kawamura et al. (< 5 µg/kg) [41] and Bemrah et al. (0.105–2.13 µg/kg) [28], while lower than those reported by Cao et al. (< LOD – 837 µg/kg) [24], Lim et al. (3–54.56 µg/kg) [22], and Osman et al. (5.57–233.78 µg/kg). In the study by Gregory et al., BPA levels in canned green beans ranged from 22 to 730 µg/kg, canned pineapple ranged from < 2 to 13 µg/kg, canned sliced peaches ranged from < 2 to 9.3 µg/kg, and canned peas ranged from 3 to 310 µg/kg [25]. In another study, the concentration of BPA recorded in canned fruits was 0.532 µg/kg, and in canned vegetables, it was 8.99 µg/kg [26]. Morgan and Clifton reported the amount of BPA in the peaches and Caesar salad was 6 and 1.4, respectively [27]. Concentration of BPA in canned vegetables in the present study (0.87–28.35 µg/kg) were similar to those reported by Choi et al. (< 1.74–32 µg/kg) [3]. The concentration of BPA in our study detected in canned vegetables was lower than that reported by Cao et al. (4.3–92 µg/kg) [23], Cunha and Fernandes (< 0.3–265.6 µg/kg) [6], and Cao et al. (< LOD – 102 µg/kg) [24], whereas higher than those reported by Bemrah et al. (3–21.5 µg/kg) [28] and Kawamura et al. (< 5–11 µg/kg) [41]. Multiple factors have been shown to have a role in the migration of BPA into canned food, including food composition (e.g. fat content), duration contact between food and can, temperature and pH values, the thickness of packaging material, and chemical properties and quantity of the migrating component [14]. Also, the type of packaging material can affect the migration of bisphenol. Geens et al. found BPA contents in the PET and glass packaging materials were greeter less than in canned foods, indicating contamination levels of BPA before filling into the container was minimal and the presence of BPA in food primarily derived from the inner lining of cans [7]. Other researchers have expressed that BPA migrates from the coating into the food, especially during the sterilization procedure, and after this process, BPA levels do not change throughout storage, even when the container is exposed to high temperatures or becomes damaged by denting [42–44]. Stojanović et al. reported that BPA concentration in canned meat products varied from 3.2 to 64.8 μg/kg following storage in military facilities and found no correlation between storage period and the contents of BPA. Additionally, high temperatures and acidic foods are the major factors that can contribute to the migration of BPA, while damaged cans play a lesser role [45]. In the recent decade, several studies have been conducted to remove bisphenol from the food matrix. Tapia-Orozco et al. reported an effective removal rate of 93.3% of BPA from canned liquid food with enzyme-based nanocomposites [46]. Also, the development of BPA-reduced or BPA-free cans can significantly mitigation of BPA contents [41]. It has also been shown that biologically degrading BPA is also a promising method. Park and Chin reported that *Bacillus subtilis* P74 results in 97.2% degradation of 10 mg/L of BPA at 9 h [47].

BPA can be released from the wall of cans into the food, in addition to this, BPA can also enter the food through the environment. When food cans are placed in high temperature conditions, the release of BPA into the food can increase. The type of can, the pH of the food, the contact time of the food, the temperature of the environment, the amount of heating before consumption, can affect the release of BPA into the food.

Table 1
The contents of BPA, sugar, fat, and pH in the canned fruit and vegetable samples.

Samples	Production time	Storage conditions	BPA (μg/kg)	Sugar %	Fat %	pH
Cherry	> 6 months	25°C	2.39	38.4	-	3.6
		4°C	0.87	38	-	3.7
	< 6 months	25°C	9.70	38	-	3.6
		4°C	2.75	38.4	-	3.9
Apricot	> 6 months	25°C	8.08	42	-	4.6
		4°C	5.64	44	-	4.5
	< 6 months	25°C	2.16	40	-	4.6
		4°C	2.29	40	-	4.7
Pineapple	> 6 months	25°C	1.81	48	-	4.2
		4°C	1.17	47.50	-	4.3
	< 6 months	25°C	2.62	46.50	-	4.1
		4°C	1.85	48	-	4.1
Lentils	> 6 months	25°C	28.35	-	32	5.6
		4°C	23.41	-	31.5	5.5
	< 6 months	25°C	11.27	-	32.2	5.6
		4°C	24.46	-	31.9	5.5
Green peas	> 6 months	25°C	1.73	-	25.3	5.9
		4°C	0.87	-	25	5.8
	< 6 months	25°C	1.53	-	24.8	5.7
		4°C	2.36	-	24.7	5.7
Eggplant stew	> 6 months	25°C	3.37	-	45.1	4.3
		4°C	1.13	-	45.5	4.4
	< 6 months	25°C	1.05	-	44.9	4.3
		4°C	1.14	-	48	4.3

Table 2
Comparison of bisphenol A found in the current study with literature.

Country	Sample	No.	Concentrations of BPA (μg/kg)		Method	Reference
			Mean	Range		
Iran	Canned fruit	12	3.44	0.87–9.7	GC/MS	Present study
	Canned vegetable	12	8.38	0.87–28.35		
Korea	Fruit	12	-	< 1.87–60.60	LC–MS/MS	3
	Vegetables	11	-	< 1.74–32		
Canada	Canned vegetable	15	20	4.3–92	GC–MS	23
Portugal	Canned fruits	20	5.1	< 0.3–10.2	GC–MS	6
	Canned vegetables	19	67.5	< 0.3–265.6		
China	Canned fruit	20	60	< LOD – 837	UPLC–MS/MS	24
	Canned vegetables	10	18	< LOD – 102		
Egypt	Vegetables and fruits	60	51.53	5.57–233.78	GC/MS/MS	8
Japan	Domestic canned fruit	8	0	< 5	GC–MS	41
	Imported canned fruit	10	20	< 5–200		
	Domestic canned vegetable	13	4.1	< 5–11		
	Imported canned vegetable	18	35	< 5–85		
Korea	Canned fruit	9	8.6	3–54.56	HPLC	22
	Canned vegetable	12	3.10	3–21.5		
France	Fruits	74	0.47	0.105–2.13	GC–MS/MS	28
	Vegetables	262	6.88	0.105–82.73		
Turkey	Olives	4	–	< 1–22	UPLC–MS/MS	21
	Canned vegetable oils	4	< 1	< 1		

3.2. Health Risk Assessment

Table 3 presents the calculated average daily intake (ADI) and target hazard quotient (THQ) of BPA exposure through consuming canned fruits and vegetables by Iranian children, and adults. Individuals can be exposed to BPA through diverse routes, with food recognized as the primary pathway of exposure. The 95th percentile ADI values of BPA in canned fruit for adults and children were 6.12E-08, and 2.16E-07 mg/kg bw/day, respectively. Also, the 95th percentile ADI values of BPA in canned vegetables for adults and children were 1.78E-07, and 6.26E-07 mg/kg bw/day, respectively (Table 3.). ADI values for children, and adults were lower than the TDI value (4 µg/kg bw/day) of BPA set by the EFSA and at acceptable ranges. The 95th percentile THQ values in canned fruit for adults and children were 1.48E-06, and5.24E-06; and in canned vegetables were 3.56E-06, and 1.27E-05, respectively (Fig. 2.). THQ values for three age classes were less than 1 and acceptable. Similar results are reported by previous research [48,49]. Based on the findings, the intake of BPA from canned fruits and vegetables in the population of Tehran, Iran is unlikely to cause human health complications. However, it is worth mentioning that since other dietary sources were not considered in the assessment, average daily intake may present an underestimate of actual exposure. Moreover, the potential synergistic impacts of BPA and other contaminants should not be ignored. Compared with other studies, Bemrah et al. reported that the range of 95th percentile ADI values of BPA in adults was 0.077–0.087 µg/kg bw/day and in children 0.119–0.141 µg/kg bw/day [28]. ADI and HI values in the study by Lim et al. were 1.509 mg/kg bw/d and HI = 0.03 [22]. Cao et al. reported 95th percentile and 50th percentile of ADI in canned Vegetables were 67 and 9.1 ng/kg bw/day (range 4.3–92 ng/kg bw/day) [23]. In another study, ADI values of BPA in canned foods food for adults was 11 ng/kg bw/day [41]. Also, the mean ADI value reported by Choi et al., in yellow peaches was 2.45 ng/kg bw/day, and in mushrooms 0.09 ng/kg bw/day [3].

Table 3
ADI and THQ values of bisphenol A exposure through canned fruit and vegetables consumption by children, and adults.

	Age	**5%**	**50%**	**75%**	**95%**
Canned fruit	adults	3.75E-08	4.85E-08	5.35E-08	6.12E-08
Canned fruit	children	1.36E-07	1.71E-07	1.88E-07	2.16E-07
Canned vegetable	adults	7.81E-8	1.21E-7	1.42E-7	1.78E-7
Canned vegetable	children	2.79E-7	4.12E-7	4.80E-7	6.26E-7

3.3. Analysis according to Principle Component Analysis (PCA) outcomes

PCA by intuitive visualization of data and results can be useful to present a very brief view of a specific purpose. The PCA analysis of BPA in canned fruit and vegetables is presented in Fig. 3. Principle Component Analysis (PCA) was performed in order to clarify the general distribution patterns or similarities of Bisphenol A in canned food. As the Euclidean space is reduced, the samples show an upper correlation together. As can be observed, the samples were well divided into three main components that present the correlation between the amount and type of PCBs in canned food.

The PCA possessed of canned vegetables and fruit a satisfactory sum of proper values with component 1, component 2 and component 3 axes in canned fruit (37.1% for P1, 28.3% for P2 and 15.6% for P3) and in canned vegetables (40.3% for P1, 25% for P2 and 16.8% for P3). The parameter plot of canned fruit (Figure. 2) was primarily structured by the component 1 axis positively characterized by the sugar and canned pineapple, and negatively by the canned cherry. Also, the component 2 axis is positively characterized by the PH, Bisphenol A, and canned Apricot, and negatively by the canned pineapple, The component 3 axis is positively characterized by the storage conditions. The parameter plot of canned vegetables (Figure. 2) was primarily structured by the component 1 axis positively characterized by the sugar and canned pineapple, and negatively by the canned cherry. Also, the component 2 axis is positively characterized by the PH, Bisphenol A, and canned Apricot, and negatively by the canned pineapple, The component 3 axis is positively characterized by the storage conditions. An interesting perspective of the effect of the canned vegetable and fruit type, PH, Sugar, storage time, and storage conditions on the Bisphenol A is obtained by treating data using analysis of principal components (PCA). PCA analysis indicates that the contaminated BPA pattern in canned lentils, apricots, cherries, pineapples, eggplant stew, and green peas samples was easily distinguishable.

4. Conclusion

The main objective of the current study was to investigate BPA contents in canned fruit and vegetable samples distributed in Tehran, Iran. BPA was found in 100% of samples. The mean concentration of BPA in canned fruit samples (ranging from 0.87 to 9.7 μg/kg) was higher than that in canned vegetable samples (ranging from 0.87 to 28.35 μg/kg). The amount of BPA in all samples was within the maximum acceptable limit. PCA indicated a close and distinctive link between the classification of our samples based on their BPA levels in the canned fruit and vegetable samples. The results of the human health risks assessment of BPA exposure through canned fruit and vegetables indicate that ADI values were less than 4 μg/kg bw/day and HQ values were less than 1, which are acceptable. According to the findings of risk evaluations, it has been concluded that consuming canned fruits and vegetables does not pose a significant health risk to consumers. Nevertheless, it is important to consider the potential effects of chronic exposure to bisphenol A from daily human diet.

Declarations

Consent for publication: All authors approve the final version for publication.

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Author Contribution

Nabi Shariatifar: Conceptualization, Supervision, Design of study, Methodology, Writing- Reviewing and Editing, Validation. Reza Hazrati-Raziabad, Ramin Aslani and Majid Arabameri: Writing- Original draft, Design of study, Methodology, Writing- Reviewing and Editing. Parisa Sadighara, and Gholamreza Jahed Khaniki: Visualization, Investigation, Methodology, Software, Data curation, Validation.

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Figures

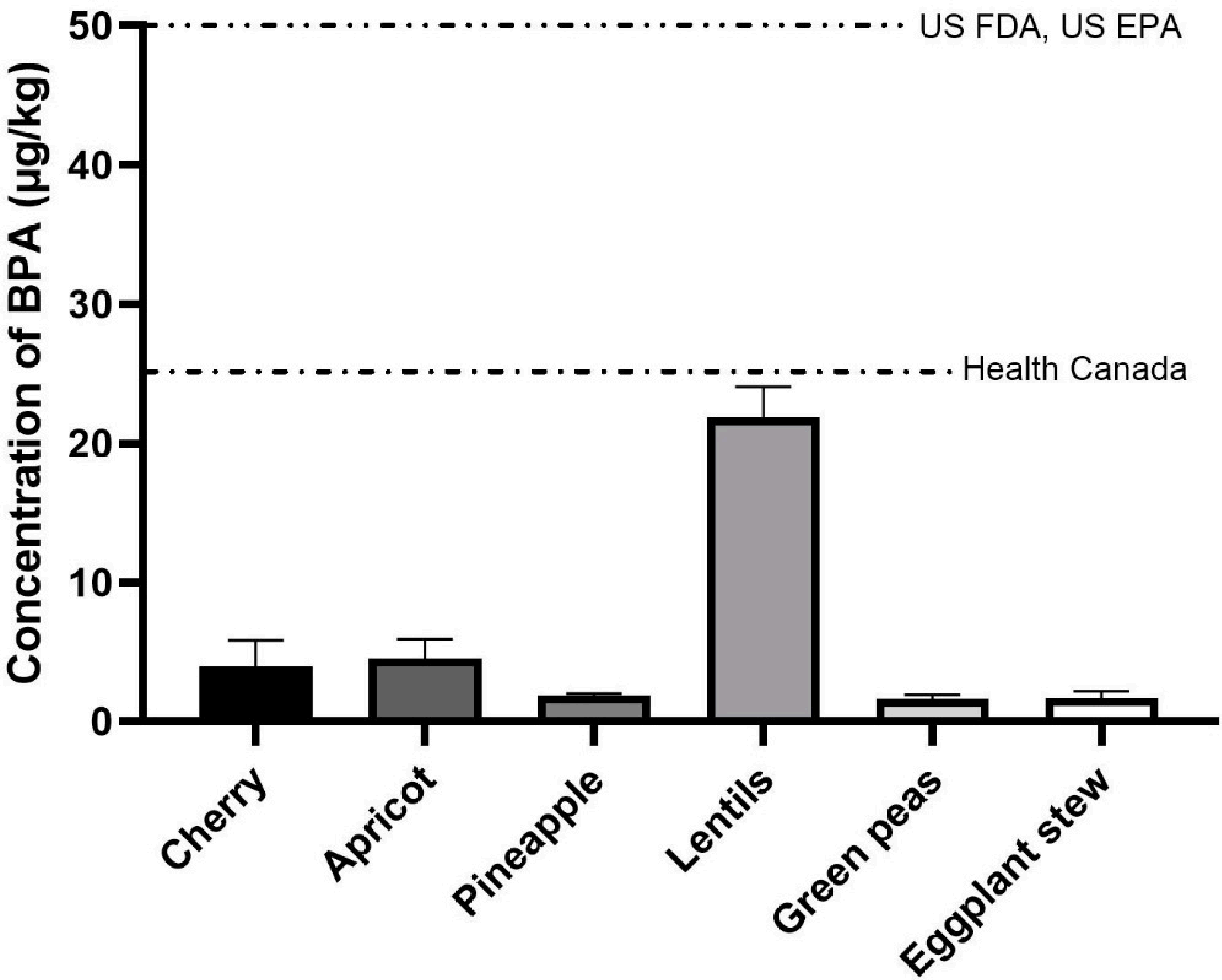

Figure 1

The mean concentration of bisphenol A in the canned fruit and vegetable samples.

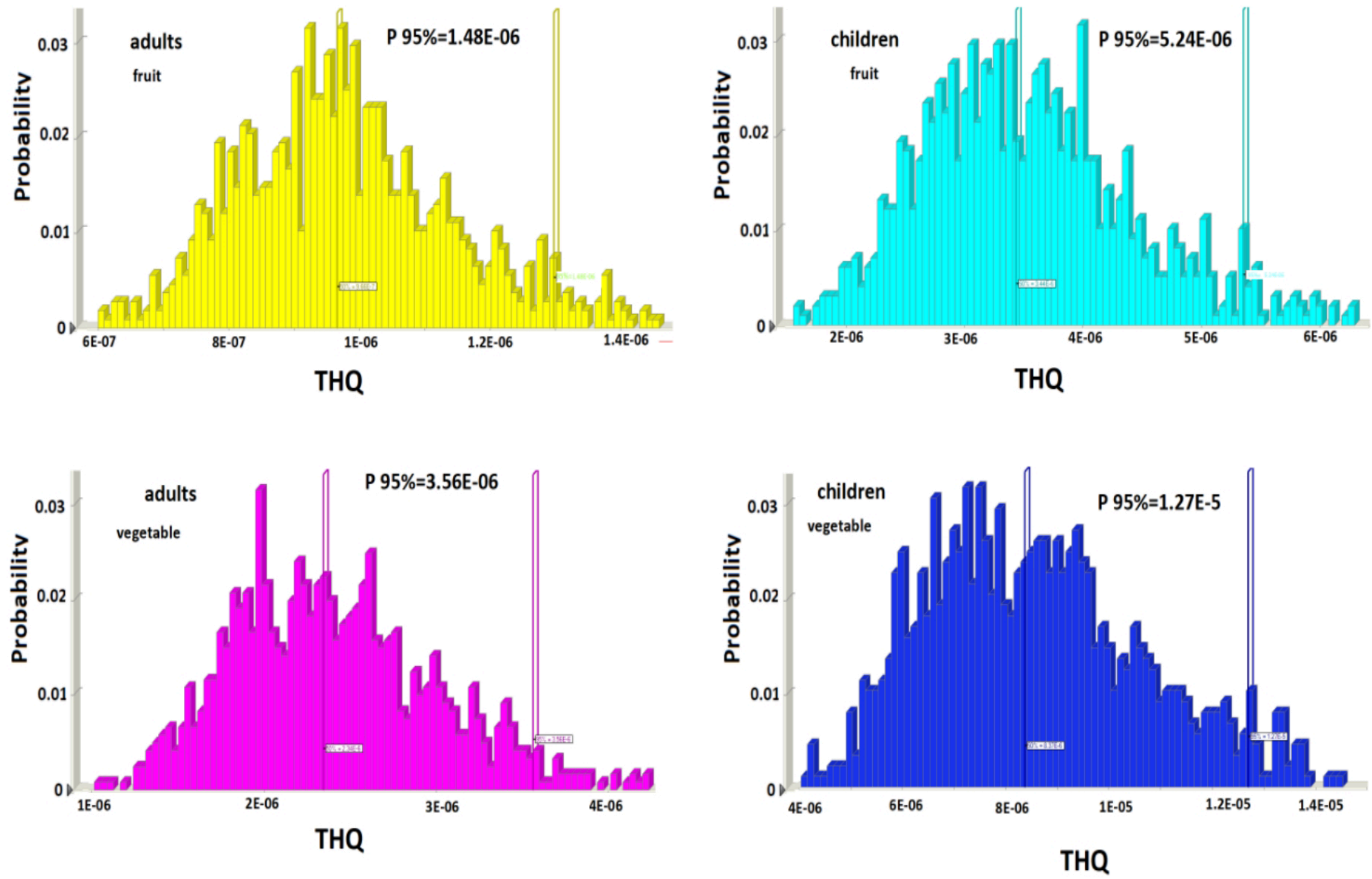

Figure 2

The Simulation results for probability THQ in canned vegetables and fruit

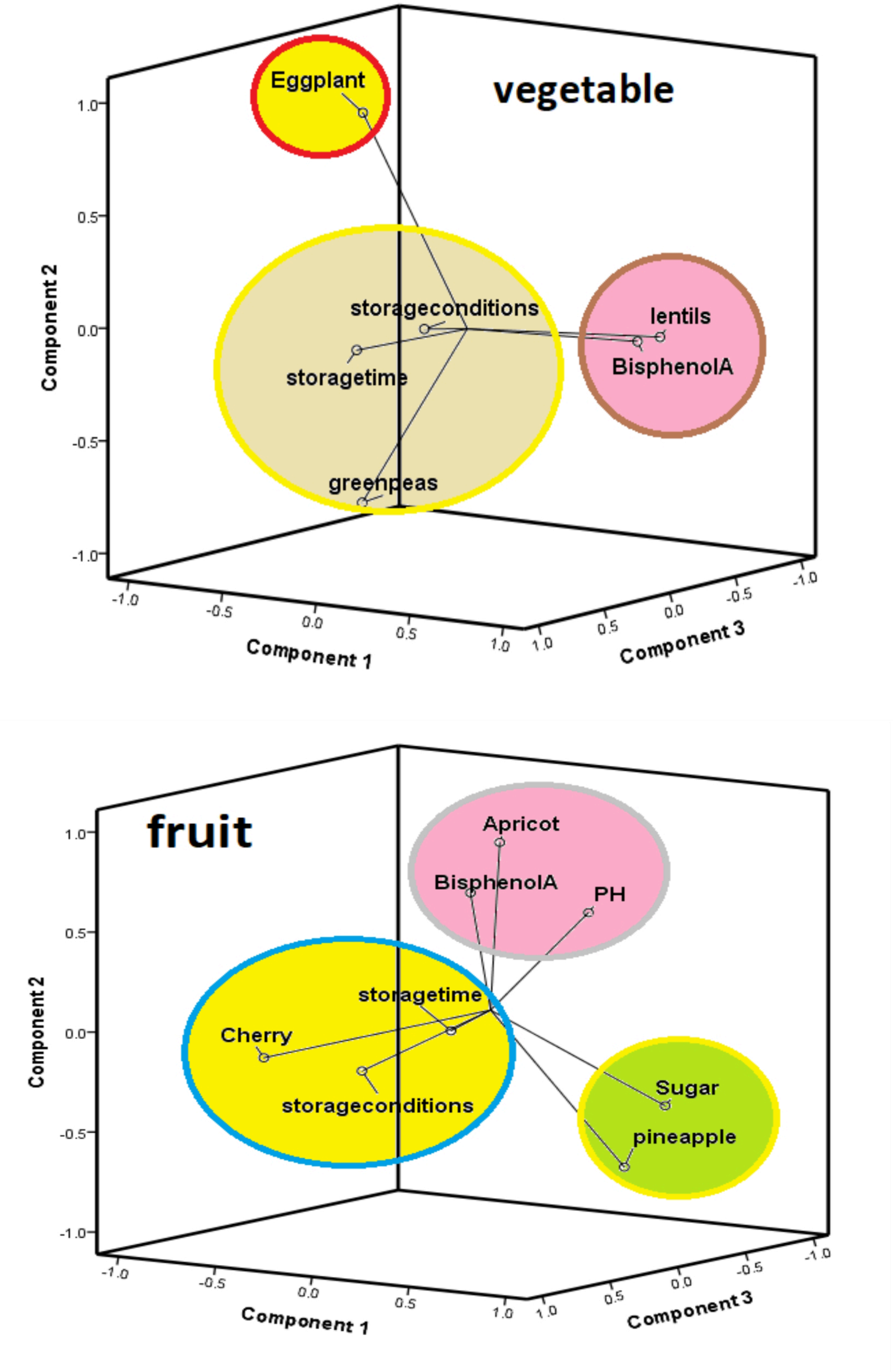

Figure 3

Principal component analysis (PCA) of BPA contents in in canned vegetables and fruit