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Determination of heavy metal content of processed fruit products from Tehran's market using ICP- OES: A risk assessment study

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ABSTRACT

In this study, the levels of Cd, Hg, Sn, Al, Pb and As of 72 samples (36 samples for fruits juices and 36 samples for fruits canned) of three different brands including of Peach, Orange, Cherry, and Pineapple (18 samples of each fruits) marketed in Tehran, Iran (2015) were evaluated using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) technique. Also, Probabilistic risk assessment (non-carcinogenic and carcinogenic risks) was estimated by models include target hazard quotient (THQ) and cancer risk (CR) in the Monte Carlo Simulation (MCS) model. However, all samples were contaminated with the heavy metals investigated, most of them not surpassed established standards. The range of concentration for Al, Sn, As, Cd, Hg, and Pb as average in fruit juices were reported as 340.62 (65.17–1039.2), 72.33 (49.76–119.4), 3.76 (1.137–18.36), 2.12 (0.89–3.44), 0.351 and 40.86 (27.87–66.1) μg/kg, respectively. The level of heavy metals measured in different kinds of fruit juices was ranked as Al > Sn > Pb > As > Cd > Hg, and for fruits canned this rank was Pb > Al > Sn > As > Cd > Hg. The range of concentration for Al, Sn, As, Cd, Hg, and Pb in fruits canned were reported as 361.23 (43.15–1121.2), 101.42 (71.45–141.61), 3.92 (1.279–19.50), 2.78 (1.09–5.56), 0.35 and 690.54 (470.56–910.14) μg/kg, respectively. The lead (Pb) concentration in 97.22% (35 out of 36 samples) of fruit juices samples surpassed Codex limit (0.05 mg/kg) and in all samples of FC was lower than the legal limit of Codex limit (1 mg/kg). All of the samples had Tin (Sn) lower than the legal limit of Codex (fruit juices 100 mg/kg and FC 250 mg/kg). The MCS indicated that the rank order of heavy metals in both adults and children based on THQ was Al > Sn > As > Pb > Cd > Hg. The THQ of Al and Sn in the FJ and FC, for both adults, and children, was considerably higher than 1 value. Also, CR of As in both adults and children were higher than 1E-6 value. Although the mean concentration of heavy metal in the FJ and FC was lower than the standard limit, the MCS indicated that adults and children are at considerable non-carcinogenic and carcinogenic risks.

1. Introduction

Fruit juices and fruits canned are commonly consumed by all age groups in all over the world especially in tropical countries as a routine part of daily diet. Moreover, they can be considered as one of the important sources of different nutrients, minerals (such as Mg and K) and vitamins (such as C, Folate, and B). In this regard, Based on Canada's food guides ½ cup and the United States recommendations 1 cup of fruit juice (100% fruit juice) should be consumed per day (Massadeh et al., 2018; Slavin and Lloyd, 2012; Zahir et al., 2009). Fruit juices are made from the extraction or pressing (mechanically and technologically) of one or mix of mature, fresh, chilled or frozen fruits (Massadeh et al., 2018; Slavin and Lloyd, 2012; Zahir et al., 2009).

In another hand, elements are divided into two groups, first, minerals as the main and beneficial group for human health such as Na, Ca, Fe, Mg, K and P also, second, heavy metals like Hg, Sn, Pb, As and Cd which cause severe problems for human health even in low levels of 10–50 mg/L (Dehelean and Magdas, 2013; Ghasemidehkordi et al., 2018; Prashanth et al., 2015; Salma et al., 2015; Savić et al., 2015). The fruit and vegetable surfaces among their production process, transport,

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preservation, and marketing might be contaminated with released pollutants from the vehicles, industrial environments such as PAHs (Polycyclic aromatic hydrocarbon), PAEs (phthalate acid esters) as well as heavy metals. Additionally, those components may be spread from several types of fertilizers and some pesticides through air and water and other environments (Gorji et al., 2016; Kouhpayeh et al., 2017; Makki and Ziarati, 2014; Massadeh et al., 2017; Moazzen et al., 2017; Ofori et al., 2013). The long period of consumption of heavy metals in high concentrations through foodstuffs such as fruits and vegetables may lead to the chronic accumulation which consequently can cause damages in heart, nervous, liver, kidney, blood, lungs, bone and spleen such as mutagenesis, carcinogenesis, teratogenesis. In this regard, several cases of human illness, disorders, deformation, and breakdowns of organs due to metal poisonousness have been reported (Makki and Ziarati, 2014; Parkar and Rakesh, 2018; Radwan and Salama, 2006) (Ghasemidehkordi et al., 2018; Mahaffey et al., 1975; Mashhadizadeh et al., 2014; Massadeh et al., 2018). Among of these elements, Lead, arsenic, mercury, cadmium, and tin can be accounted as main threats to human health (Fakhri et al., 2017; Hadiani et al., 2015; Shahsavani et al., 2017). Accumulation of Pb and Cd can cause skeletal damage, cancer, reproductive deficiencies, brain damage, kidney dysfunction and poisoning. Mercury (Hg) is also one of the most dangerous heavy metals affecting the brain and spinal cord (central nervous system) (Adegbola et al., 2015; Ahmadi and Ziarati, 2015; Akan et al., 2013). Moreover, in term of As, it causes dangerous influences to humans body like: hematological, dermal changes, gastrointestinal, respiratory, neurological, cardiovascular, genotoxic, reproductive, carcinogenic and mutagenic effects (Ali and Al-Qahtani, 2012; Anwar et al., 2014; Eleboudy et al., 2016).

The processed fruit juices and fruits canned can be considered as potential sources of toxic metals (even with consuming low concentrations) (Adegbola et al., 2015; Ahmadi and Ziarati, 2015; Ghasemidehkordi et al., 2018; Ibraheen and Abed, 2017; Izah et al., 2016). In the case of canned food the mentioned risks are higher, due to the migration of heavy metals from the metallic packaging material into the products (Blunden and Wallace, 2003; Khalafalla et al., 2016; Kocak et al., 2005; Maduabuchi et al., 2007). Hence, the determination of metal contents in fruit juice and fruits canned are a matter of concerns for in both safety and nutritional aspects. Therefore, determination of heavy metals' content and further comparison with the standard in food products especially fruit juices and fruits canned in order to evaluate their safety have been a matter of the subject for several studies in the last decades (Dehelean et al., 2016; Krejpcio et al., 2005; Rezaei et al., 2014; Salma et al., 2015; Savić et al., 2015). According to Iwegbue et al. (2008), the concentration of heavy metals (Fe, Cu, Cr, Pb, Ni, Mn, Zn, and Cd) in six brands of fruit juices from Nigeria were measured as 23.59–97.72, 0.01–5.15, 0.01–3.43, 0.01–4.60, 0.13–7.93, 0.01–1.37, 4.95–48.23 and 0.01–5.68(mg/kg),respectively (Iwegbue et al., 2008). Based on the findings of Krejpcio et al. (2005), however, the concentration of Copper, Zinc, Lead and Cadmium in 88% of fruit juices most samples met the national standard, 12% exceeded the permissible limits for Lead and Cadmium (3 and 9%), respectively (Krejpcio et al., 2005). The mean concentration of Cd, Co, Cr, Cu, Ni, Pb, Zn and Fe in 5 brands of fruit juices were reported as 0.003–0.007, 0.003–0.32, 0.001–0.03, 0.001–1.02, 0.001–0.10, 0.003–0.19, 0.020–1.10 and 0.56–6.35(mg/L) (Onianwa et al., 1999). In this regard, Identifying and controlling heavy metals in food, including juice fruits and fruits canned, are of great importance to human health.

Studies have shown that only comparing concentrations of contaminants with standards limits cannot accurately reflect the health status of consumer groups, as some adverse clinical effects have been observed in concentrations below the standard limits (Adel et al., 2016; Fakhri et al., 2018a; Jafari et al., 2018; USEPA, 2017). Therefore, health risk assessment is necessary to obtain potential health risks with considering uncertainties. Monte Carlo Simulation (MCS) method is one of the primary methods that can be used to detect the uncertainties linked human health risks (Fjeld et al., 2007; Hastings, 1970), has been defined as a averages of variability in health risk assessments and quantifying uncertainty by the united states environmental protection agency (USEPA) and national academy of the council (NRC) (NRC, 1994; USEPA, 1997).

Therefore, the goal of this research was to detect and assess the concentrations of As, Al, Hg, Pb, Cd, and Sn in Peach, Orange, Cherry and Pineapple fruit juices and canned of three brands collected from the Tehran, Iran during 2016. Also, health risk assessment in the adults and children age groups by Target hazard quotient (THQ) and cancer risk (CR) in the MCS method were estimated.

2. Materials and methods

2.1. Samples collection

A total of 72 samples (n = 36 for fruit juice and n = 36 for fruits canned) of 3 different brands, including of Peach, Orange, Cherry and Pineapple juices were selected randomly from local supermarkets in Tehran, Iran, 2016. All samples were kept in a glass container (in the sterile condition) at 4 °C until preparations and analyses that were done on the same day.

2.2. Chemicals and reagents

All of the chemicals and reagents were analytical grade and provided from Merck, (Darmstadt, Germany). De-ionized water was used throughout the research and nitric acid (65%), with a grade of spectroscopic, provided by Merck (Darmstadt, Germany).

2.3. Sample preparation

Concentrations of six trace elements (Hg, As, Sn, Pb, Al, and Cd) were analyzed in all samples. In this research closed vessel, acid decomposition in microwave oven system was used to minimize the effects of the organic matrix and also prevents the possibility of sample pollution and losses of analytes. Duplicate of 2.0 mL of each fruit juice and ground canned fruit samples were taken into microwave vessels. Twenty mL of mix concentrate nitric acid–hydrogen peroxide (9:1, v/v) were added to each vessel and well shaken and kept at room temperature for 10 min until the samples were homogenized. Afterward, the vessels were retained in the covered Polytetrafluoroethylene (PTFE) container. As next step, for 15 min samples were heated (at 80% of total power (1800 W)) following one-stage digestion programmed. After cooling, to eliminate the extra acid, the subsequent solutions were evaporated to semi-dried mass, and afterward diluted up to 50.0 mL in volumetric flasks with deionized water and retained as a stock sample solution.

2.4. Inductively coupled plasma atomic emission spectrometry (ICP-OES) conditions

All analysis of fruit juices and fruits canned samples were performed using an inductively coupled plasma optical emission spectrometer. ICP-OES used was Spectro Arcos (SPECTRO, Germany) with Torch type of Flared end EOP Torch 2.5 mm. Operating optimal parameters were: RF generator (1400 W), Argon was plasma, auxiliary and nebulizer gas. Plasma gas flow, auxiliary gas flow, and nebulizer gas flow were 14.5, 0.9 and 0.85 (L/min), respectively. After that, sample uptake time, rinse time, initial stabilization time was 240 total, 45 and preflush 45 s, respectively, delay time and time between replicate analysis were zero. The measurement replicate was three-time, the frequency of RF generator was 27.12 MHz (resonance frequency). Type of detector Solid state and spray chamber was CCD and Cyclonic, Modified Lichte, respectively. Sample delivery pump type was four-channel, software controlled; peristaltic pump enables exact sample flows. Prewash pump

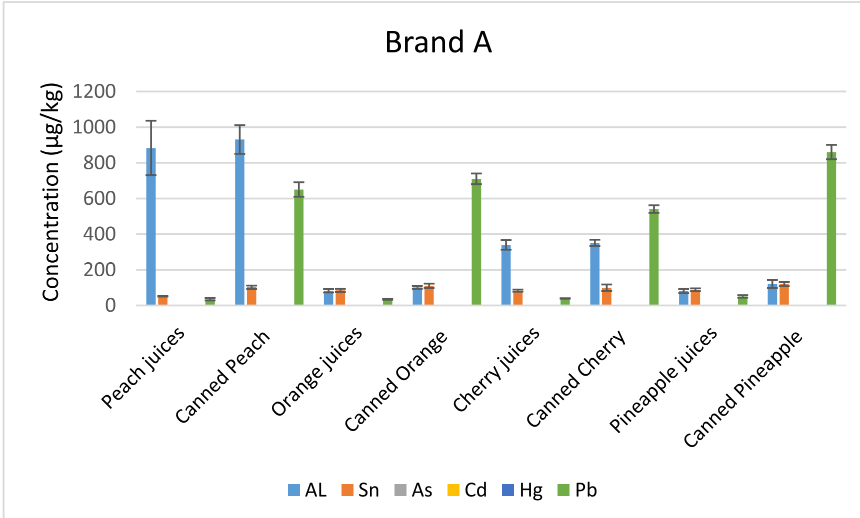

Fig. 1. Mean ± SD for heavy metal (ppb) contents of juices and canned in Brand A (µg/kg).

speed (rpm) was 60(for 15 s), 30 (for 30 s) and Prewash time was 45 s at the end sample injection pump speed was 30 rpm.

2.5. Health risk assessment

The *Health risk assessment* (non-carcinogenic and carcinogenic risk) of heavy metals in fruit juices and fruit canned in the adults and children age groups consumers were estimated via a model described by (Dadar et al., 2017; Fakhri et al., 2017; IRIS, 2010; USEPA, 2010). The Target hazard quotient (THQ) was used to calculate the non-carcinogenic risk of heavy metals (Equation (1)) (Fakhri et al., 2017; Shahsavani et al., 2017; Zafarzadeh et al., 2017).

$$THQ = \frac{CDI}{RfD} \quad (1)$$

Where chronic daily intake (CDI) is the estimated amount of intake heavy metals per kilogram body weight; RfD is oral reference dose of the heavy metals (mg/kg.d) via the oral exposure route.

RfD for Cd, Hg, Sn, Al, Pb and As is 0.0005, 0.0001, 0.0003, 0.0004, 0.0085 and 0.0003 mg/kg.d, respectively (USEPA, 2015).

The CDI was calculated by the Equation (2) (Abtahi et al., 2017; Adel et al., 2016; Fakhri et al., 2017).

$$CDI = \frac{C \times IR_i \times EF_i \times ED_i}{BW_i \times AT} \quad (2)$$

Where, C is the concentration (mg/L) of heavy metal in fruit juices and fruit canned (mean and 95% confidence interval concentration of heavy metals), IRi is ingestion rate for adults and children consumers Iran is 0.030 and 0.012 kg/n-day, respectively (Statista, 2013); EFi is the exposure frequency (350 days/year for both age groups); EDi is the exposure duration (for adults and children is 70 and 6 years, respectively); BWi is the body weight (for children and adults is 20 and 70 years, respectively), AT is the average time lifespan (EF × ED) (adults and children is 25550 and 2190 days, respectively). When the THQ > 1, potential adverse effects are likely; and if THQ ≤1, adverse effects are not likely (Dadar et al., 2017; Fakhri et al., 2018a, 2018b; Ghasemidehkordi et al., 2018).

In order to estimate total target hazard quotient (TTHQ) via multiple heavy metals, the sum of THQ_i for individual heavy metal was estimated by the Equation (3) (Shi et al., 2011; USEPA, 2015):

$$TTHQ = \sum_{i=1}^{n} THQi \quad (3)$$

For an estimate, carcinogenic risk, (R) was calculated using the Equation (4) (Heshmati et al., 2018; Kim et al., 2013; USEPA, 2000):

$$CR = CDI \times CSF \times ADAF \quad (4)$$

Where, CSF is the cancer slope factor (kg.day/mg), the probability of the one substance to increase cancer risk via oral exposure route; and ADAF is age-dependent adjustment factor (for adults and children is 1 and 3 value, respectively) (Huang et al., 2016; USEPA, 2016). CSF for As is 1.5 kg.day/mg (USEPA, 2000a), respectively. CSF for Cd, Hg, Sn, and Al was not available. In this study value of estimated CR, was compared with the maximum acceptable risk suggested by the USEPA which is ≤ 1E-6 (USEPA, 2015).

2.6. Monte Carlo simulation (MCS) method

Uncertainties can occur during estimate risk assessment (Chen et al., 2012). When used of single-point values to estimate the risk of exposure to pollutants like heavy metals, high uncertainty is observed. Therefore, in this study, MCS as a probabilistic method was used to decrease the uncertainties (Ghasemidehkordi et al., 2018; Ru et al., 2013; van der Voet et al., 2007). Health risk assessment was performed using MCS method by Crystal Ball software (version 11.1.2.4, Oracle, Inc., USA). The number of repetitions for each model was at 10,000, and also percentile 95% of THQ and CR in the MCS method was considered as a benchmark for endangering health risk of consumers (Qu et al., 2012).

2.7. Statistical analysis

Statistical analyses for calculation of mean and standard deviation of measured concentrations were done with the Statistical Package for the Social Sciences (SPSS Inc., USA) version 18.0 for windows.

3. Results and discussions

3.1. The concentration of heavy metals

The range of concentration for Al, Sn, As, Cd, Hg, and Pb in fruit juices were reported as 340.62 (65.17–1039.2), 72.33 (49.76–119.4), 3.76 (1.137–18.36), 2.12 (0.89–3.44), 0.351 and 40.86 (27.87–66.1) µg/kg, respectively. The range of concentration for Al, Sn, As, Cd, Hg, and Pb in fruit canned were reported as 361.23 (43.15–1121.2), 101.42 (71.45–141.61), 3.92 (1.279–19.50), 2.78 (1.09–5.56), 0.35 and 690.54 (470.56–910.14) µg/kg, respectively.

According to Figs. 1–3, almost in all brands, concentrations of heavy metals in fruits canned were higher than fruit juices. Results showed the

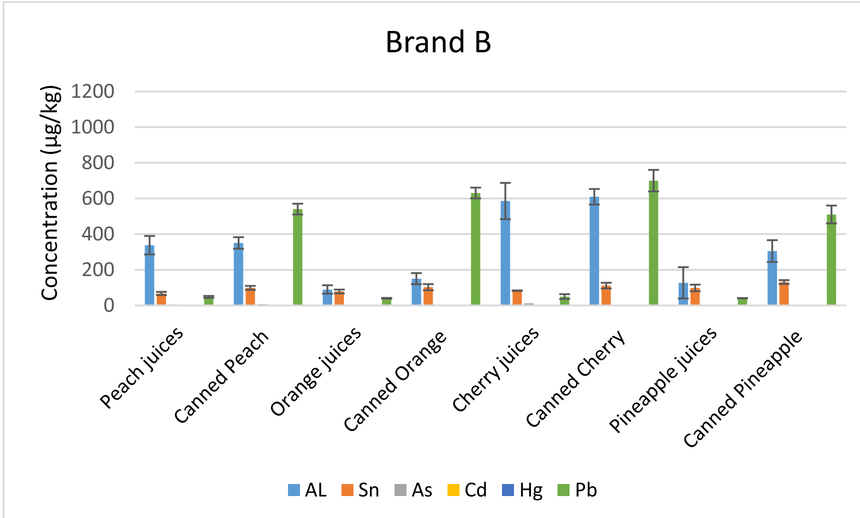

Fig. 2. Mean ± SD for heavy metal (ppb) contents of juices and canned in Brand B (µg/kg).

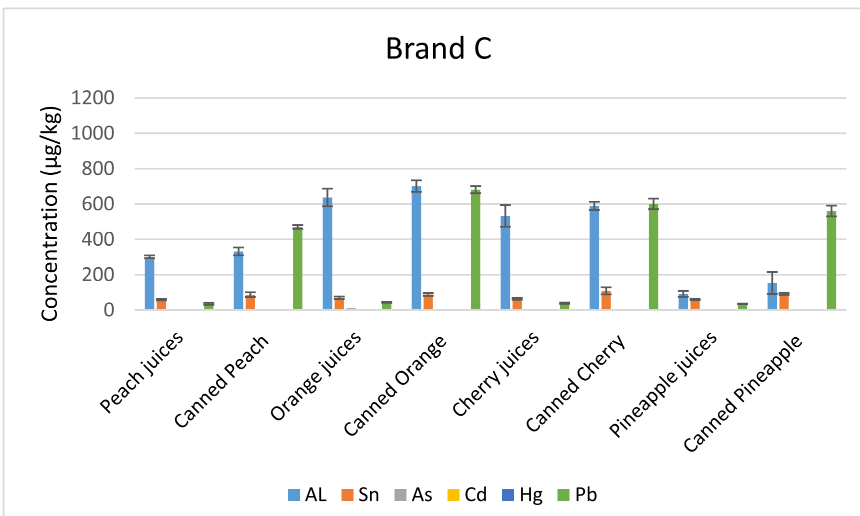

Fig. 3. Mean ± SD for heavy metal (ppb) contents of juices and canned in Brand C (µg/kg).

highest concentrations of heavy metal were nominated to Al (in brand A and C), and Pb (in brand B) and the lowest concentrations of heavy metal was Hg (0.35 µg/kg) in all samples. Also, the pineapple juice had a minimum level of heavy metals, and canned orange, cherry, and peach had a maximum level of heavy metals. Our findings showed that canned peach had a maximum level of Al (brand A) and Cd (brand C). Additionally, canned pineapple had a maximum level of Sn and Pb (brand A) and Sn (brand B). The maximum levels of Al, Pb, and Sn were detected in canned cherry (brand B) and (brand C), respectively. Also, canned orange had a maximum level of Cd (brand B) and Al and Pb (brand C)·In another hand, peach juices had a minimum level of Sn (in all brands), Cd (brand A and B) and Pb (brand A). The minimum level of Al, Pb were determined in Pineapple juices (brand A and C) and (brand C), respectively. Moreover, orange juices had a minimum level of Al and Pb (brand B).

The lead (Pb) concentration in 97.22% (35 out of 36 samples) of fruit juice samples was higher than Codex limit (50 µg/kg) and in all samples of fruit canned was lower than the legal limit of Codex limit (1000 µg/kg). In 100% of samples had Tin (Sn) lower than the legal limit of Codex (fruit juices 100 mg/kg and canned fruit 250 mg/kg).

The results are in agreement with the previous study in Bangladesh, in which the reported lead contamination in fruit juices was the highest in orange juice (0.2 mg/kg) and was lowest in mango juice (0.012 mg/kg) (Tasnim et al., 2010). The high contamination with heavy metals in 15 different brands fruit juice samples, widely consumed in Saudi Arabia was demonstrated by Farid and Enani (2010). Considering their results, the concentration of cobalt in samples was reported about 7.93 ± 1.02 µg/L(Farid and Enani, 2010). As well as, the conducted study by Iwegbue et al. (2008) reported that range of Pb and Cd in canned fruit samples was 0.06–1.93 and 0.002–0.49 mg/L, respectively (Iwegbue et al., 2008). Ackah et al. (2014), measured the concentration of heavy metals in soft drink samples marketed in Ghana including 4 pineapple-based fruit drinks, 8 citrus-based fruit juices, 1 soya-based drink, 3 cola carbonated drinks, 1 apple-based fruit drink, and 6 cocktail fruit drinks. The mean concentration of cobalt, cadmium, and lead in all samples, were reported as 0.071 ± 0.049 mg/L 0.032 ± 0.012 mg/L, 0.178 ± 0.091 mg/L respectively (Ackah et al., 2014). Leao et al. (2016) measured cadmium (Cd) and tin (Sn) in canned foods in Brazil that the concentrations level were 3.57–62.9 ng/g and 4.06–122.0 mg/kg for cadmium (Cd) and tin (Sn), respectively. In all samples, the Cd and Sn contents were lower than the permissible max levels for these metals in canned foods in the Brazilian legislation (Leao et al., 2016). Also, Santos Froes et al. (2009) determined the level microelements in fruit juice of Brazil; all elements had LOD and LOQ

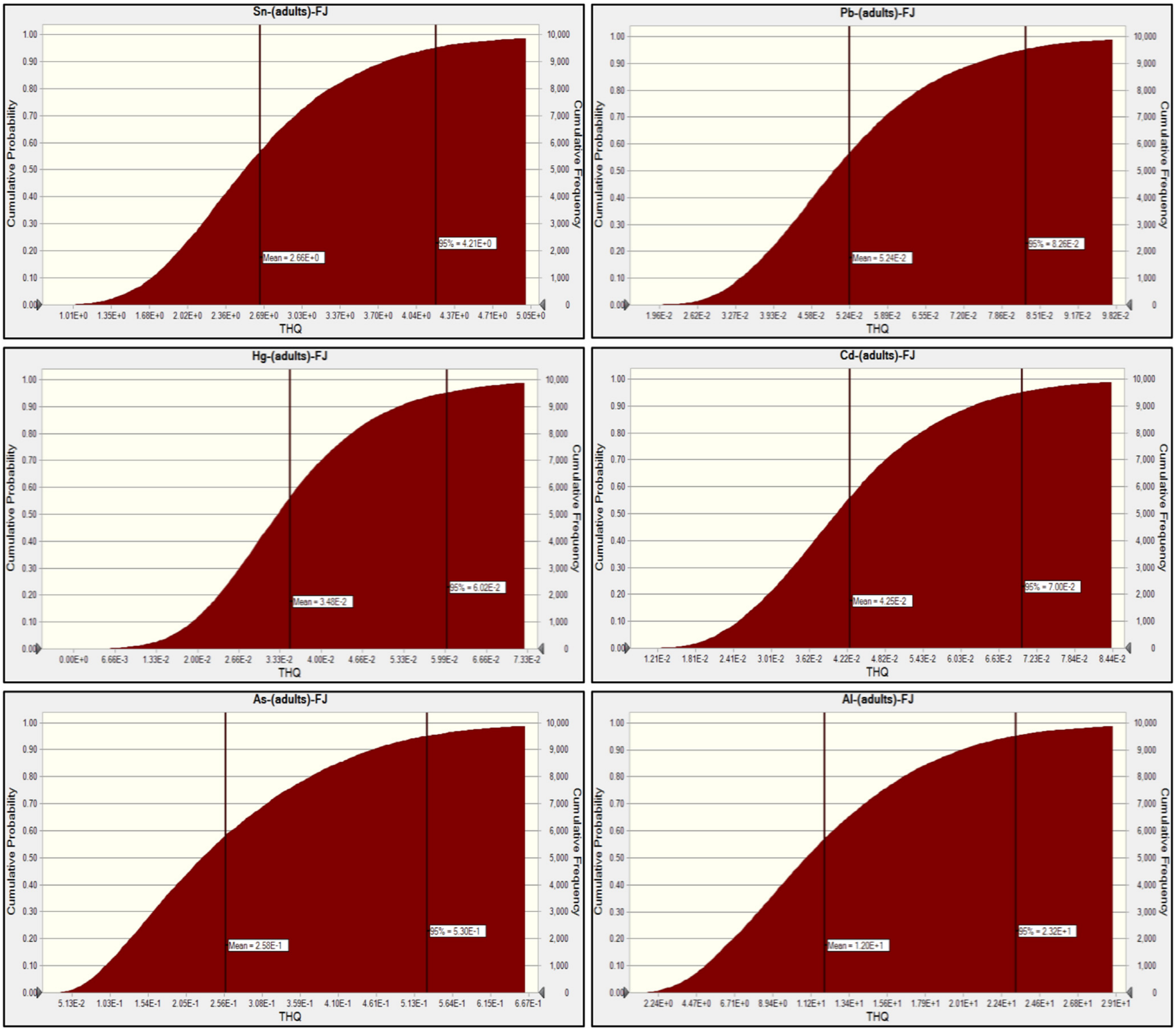

Fig. 4. Target hazard quotient (THQ) in the adult's consumers due to fruit juicy (FJ) content of heavy metals ingestion.

values less than the maximum permitted values by corresponded regulation (Froes et al., 2009). The conducted study by Szymczycha-Madeja and Welna (2013) regarding fruit juice samples of Poland showed that the highest concentrations of Al and Pb were determined in plum juice (1.34 ± 0.004 and 0.786 ± 0.028) and the lowest in orange juice (0.03 ± 0.004 and 0.091 ± 0.007), respectively (Szymczycha-Madeja and Welna, 2013).

In similar studies in Italy by Coco et al. (2006), the average content of heavy metal contamination in fruit juice samples was in the range < LOD–3.0 for cadmium and 8.2–21.3 μg/L for the lead (Coco et al., 2006). Hamurcu et al. (2010) shown in fruits grown at the roadsides Turkey, the average level of heavy metals were Pb 2.86–1.54 mg/kg, Cu 0.27–0.05, Cr 0.32–0.18 and Ni 0.68–0.26.

Massadeh at all (2018) in Jordan determined the Lead (Pb), Arsenic (As), and Cadmium (Cd) of varies fruits canned brands and vegetables including canned juice (pineapple), canned tomato sauce (ketchup), canned whole carrots and canned green beans. They showed metal concentration levels in the samples were in the range of 0.50–0.60 mg/kg for Cd, 2.6–3.0 mg/kg for Pb and 2.50–5.10 mg/kg for As. The outcomes showed lead and arsenic were the dominant contaminants in the majority of samples, while the lowest concentrations were attributed to Cadmium (Massadeh et al., 2018). Pavel Diviš et al. determined Tin (Sn), Cadmium (Cd) and Lead (Pb) in fruits canned in Czech in 2017, that results show that canned grapefruit was the most contaminated sample with tin (Sn) (59.8 ± 1.9 mg/kg). The age of cans had no significant effect on the measured concentration of Sn. The concentration of cadmium (Cd) and lead (Pb) in the analyzed samples were determined at a low level (Diviš et al., 2017). The results of similar research in Iran showed storage time did not significantly affect the concentration of Tin (Sn), and most of the heavy metals in canned. The outcomes demonstrated that maximum and minimum concentrations for Tin in canned food samples was (357.88 ± 14.33 and 26.54 ± 5.73 mg/kg DW), respectively (Makki and Ziarati, 2014). The contamination by arsenic in canned and non-canned beverages (Nigeria) was investigated by Maduabuchi et al. (2007). According to obtained results, 33.3% of the canned drinks had as levels that exceeded the maximum contaminant level (MCL) of 0.01 mg/L established by EPA (the United States Environmental Protection Agency) while 55.2% of non-canned fruit drinks surpassed the MCL. The As concentration levels for the canned fruit drinks were 0.003–0.161 mg/L and for the non-canned fruit drinks were 0.002–0.261 mg/L (Maduabuchi et al., 2007).

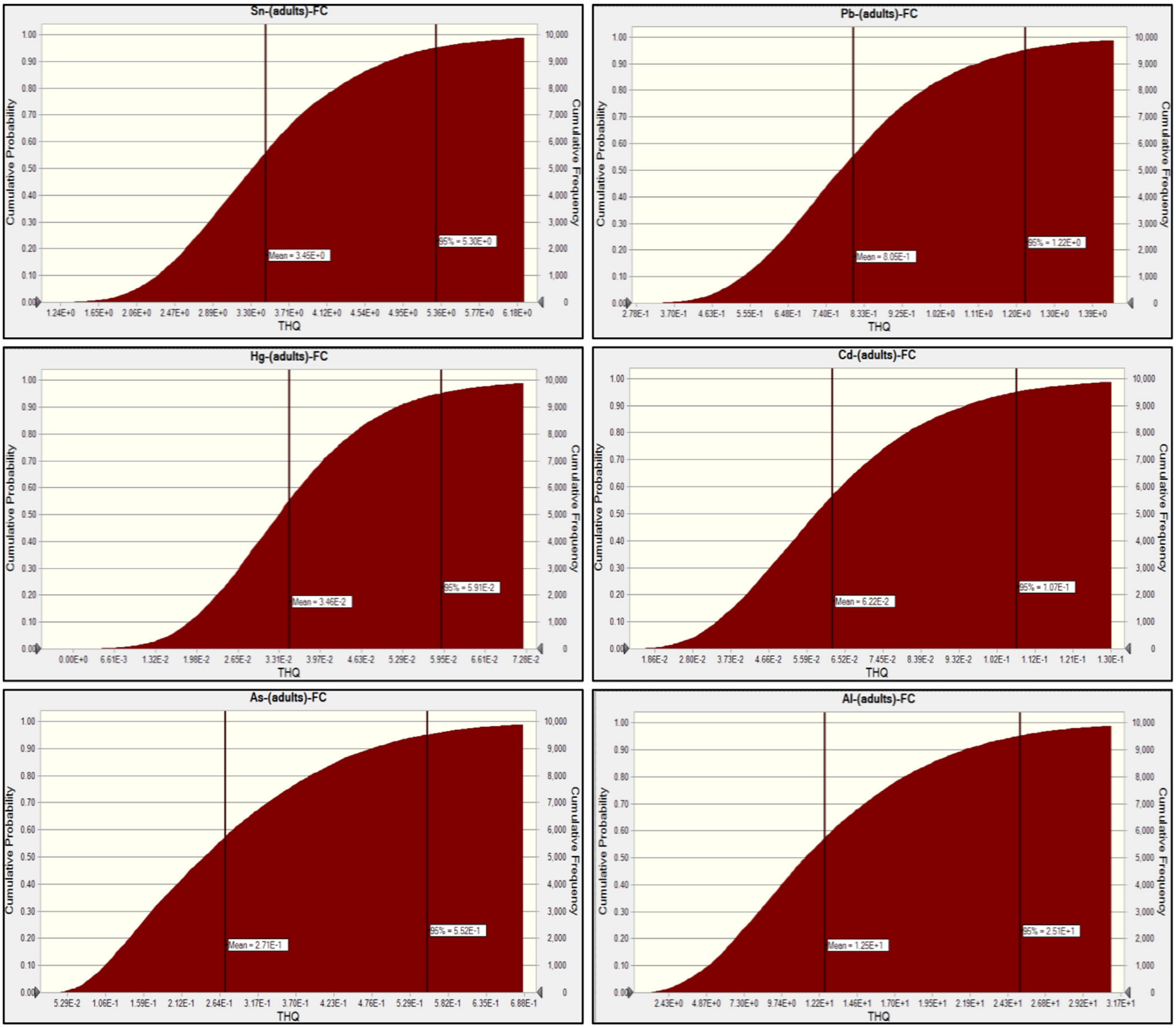

Fig. 5. Target hazard quotient (THQ) in the adult's consumers due to fruits canned (FC) content of heavy metals ingestion.

According to Williams et al. (2009), however, in beverages from Nigeria, Pb level ranged from 0.08 to 0.57 mg/L in the fruit juices, it was not seen in the carbonated drinks (Williams et al., 2009). Considering to findings of Bıngöl et al. (2010), in soft drinks from Turkey, mean levels of As, Cd, and Pb were found to be 0.037, 0.005 and 0.029 mg/kg, respectively (Bıngöl et al., 2010).

The high level of contamination by the heavy metals current study can be correlated to contamination of fruits by soil and water during of growth, water usage during of process, failures in safety of equipment and instruments and further migration of heavy metal from packaging. As all fruits are in the same range as the pH (~3.3–4.2), the pH cannot be a decisive factor.

3.2. Health risk assessment

3.2.1. Non-carcinogenic risk

The rank order of heavy metals in fruit juice based on percentile 95% of the THQ in the adults was Al (23.2) > Sn (4.21) > As (0.53) > Pb (0.08) > Cd (0.07) > Hg (0.06) (Fig. 4); and fruit canned was Al (25.1) > Sn (5.3) > As (0.55) > Pb (1.22) > Cd (0.01) > Hg (0.05) (Fig. 5). The percentile 95% of the THQ in the adults for fruit canned ~1.25 time higher than fruit juice. The rank order of heavy metals in the fruit juice based on percentile 95% of the THQ in the children was Al (23.5) > Sn (4.18) > As (0.52) > Pb (0.08) > Cd (0.07) > Hg (0.05) (Fig. 6); and fruit canned was Al (24.9) > Sn (5.3) > As (0.56) > Pb (1.22) > Cd (0.01) > Hg (0.05) (Fig. 7). Because of concentration of Al was higher than others metals (Table 2, 3 and 4) and also its Rfd was very low (0.0004 mg/kg.d) (USEPA, 2015), therefore THQ of Al was higher than other heavy metals.

The percentile 95% of the THQ in the children for fruit canned ~1.05 time higher than fruit juice. TTHQ in the adults due to fruit juice and canned fruit ingestion was 27.95 and 32.15; and for children, 27.90 and 31.55, respectively (Fig. 8). The TTHQ in both adults and children age groups consumers for fruit canned ~1.15 times higher than fruit juice.

3.2.2. Carcinogenic risk

The percentile 95% of the CR in the adults due to As in the fruit juice and fruit canned was 1.20E-4 and 1.27E-4 respectively (Fig. 9). The percentile 95% of the CR in the children due to As in the fruit juice and fruit canned was 2.44E-4 and 2.58E-4, respectively (Fig. 9). Also

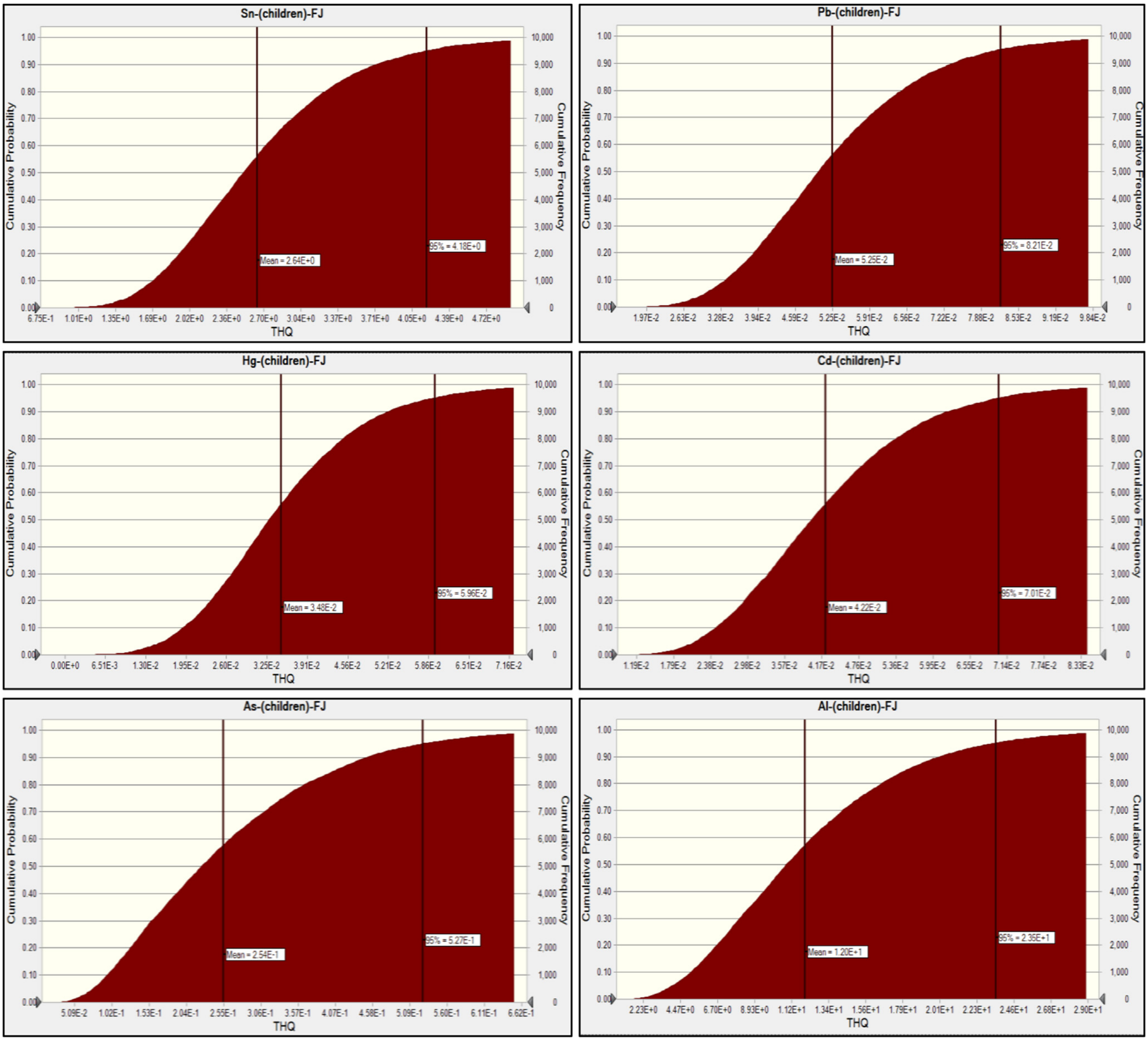

Fig. 6. Target hazard quotient (THQ) in the children consumers due to fruit juicy (FJ) content of heavy metals ingestion.

the CR due to As in the children age was higher than adults due to higher ADAF in the children.

Cadmium, lead, aluminum, arsenic, mercury, and tin are very harmful elements for human body and also, infant formula (Kamkar et al., 2010; Shariatifar et al., 2017). Cd and Sn are toxic to human biosystem even in low concentrations. Toxicity of heavy metals is recognized as one of the leading environmental and food safety risks. Pb affects humans and animals, but the effects of Pb in children are most serious. Cd is a carcinogenic and toxic metal. Cd is cumulative and absorbed into the body of human from the dietary origin and Tobacco smoking (Krejpcio et al., 2005). The main origin of human exposure to lead and cadmium comes from the food (is about 80–90% of daily doses) (Krejpcio et al., 2005; Satarug and Moore, 2004). Aluminum intake among physicians and scientists has long been discussed, and poisoning with this metal in renal patients (with chronic failure) is one of the major clinical problems that involving trace heavy metal poisonousness (Savory et al., 1994). Several factors such as exhaustion gases, industry wasted, and wastewaters are affecting the heavy metal level of fruits and vegetables and other plants. One of the pollutant elements of the roadside plants is probably exhaustion gases. The plants that grow in roadside and factory and other industrial environment are possibly rich in heavy metals. Furthermore, fruits should not be picked up from contaminated environment whereas their mineral compositions modify according to their growing environment, water, and soil (Ivey and Elmen, 1986). However, there is no information about fruits used for juice production in sampling factories, but depending on the planting environment for agricultural products (i.e., water, soil, air pollution), Equipment for juice and canned production, transport containers, and storage containers could be counted as important sources of heavy metal pollution. It appears that the use of suitable packaging, stainless steel containers and agricultural products grown in environment and soils with minimum heavy metal contamination might play a main role in the reducing heavy metal in fruit juices.

4. Conclusions

In the study concentration of heavy metals in fruit juices and fruits canned from Tehran's market using ICP-OES was measured and health risk of adults and children via MCS was estimated. The higher concentrations of heavy metals in fruits canned in comparison with fruit

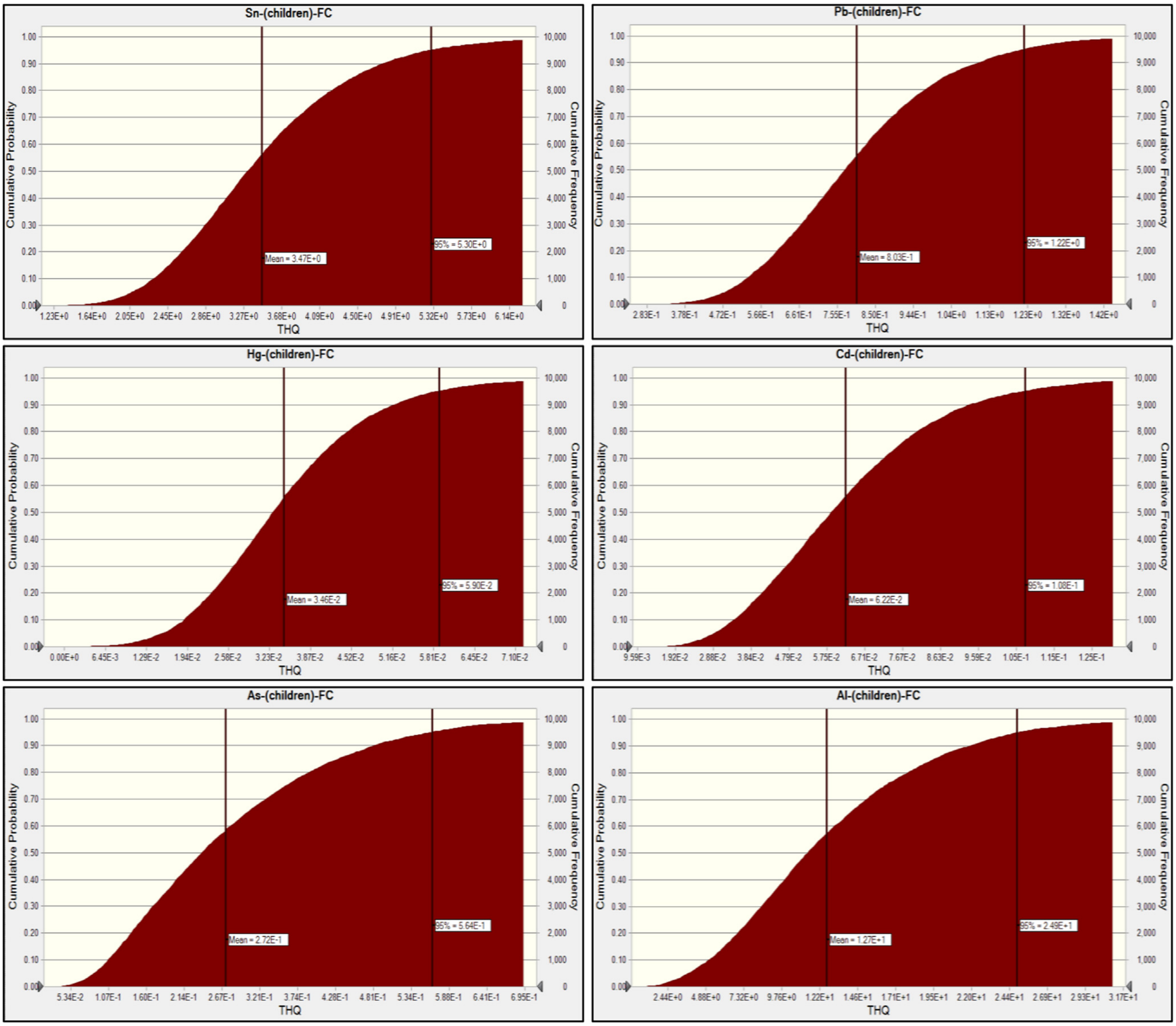

Fig. 7. Target hazard quotient (THQ) in the children consumers due to fruit canned (FC) content of heavy metals ingestion.

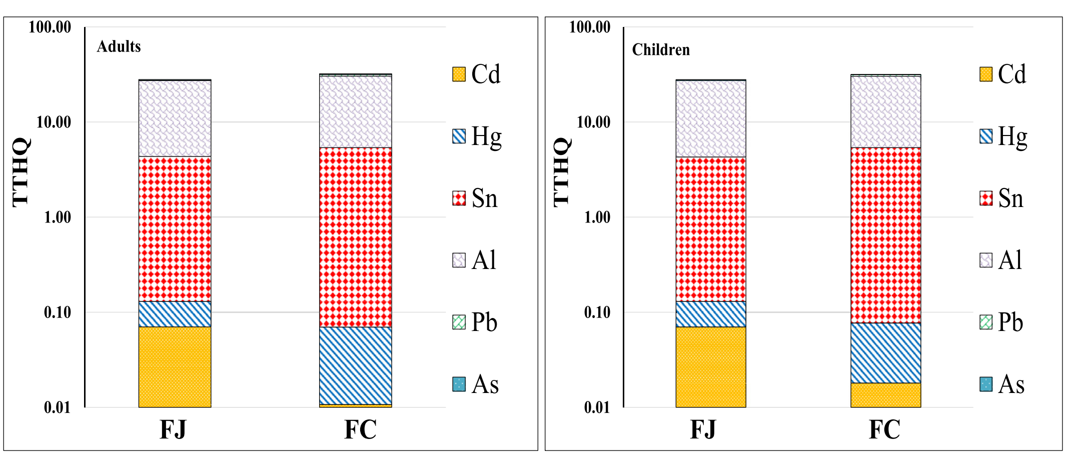

Fig. 8. Total target hazard quotient (TTHQ) in the adults and children due to fruit juice (FJ) and fruit canned (FC) content of heavy metals ingestion.

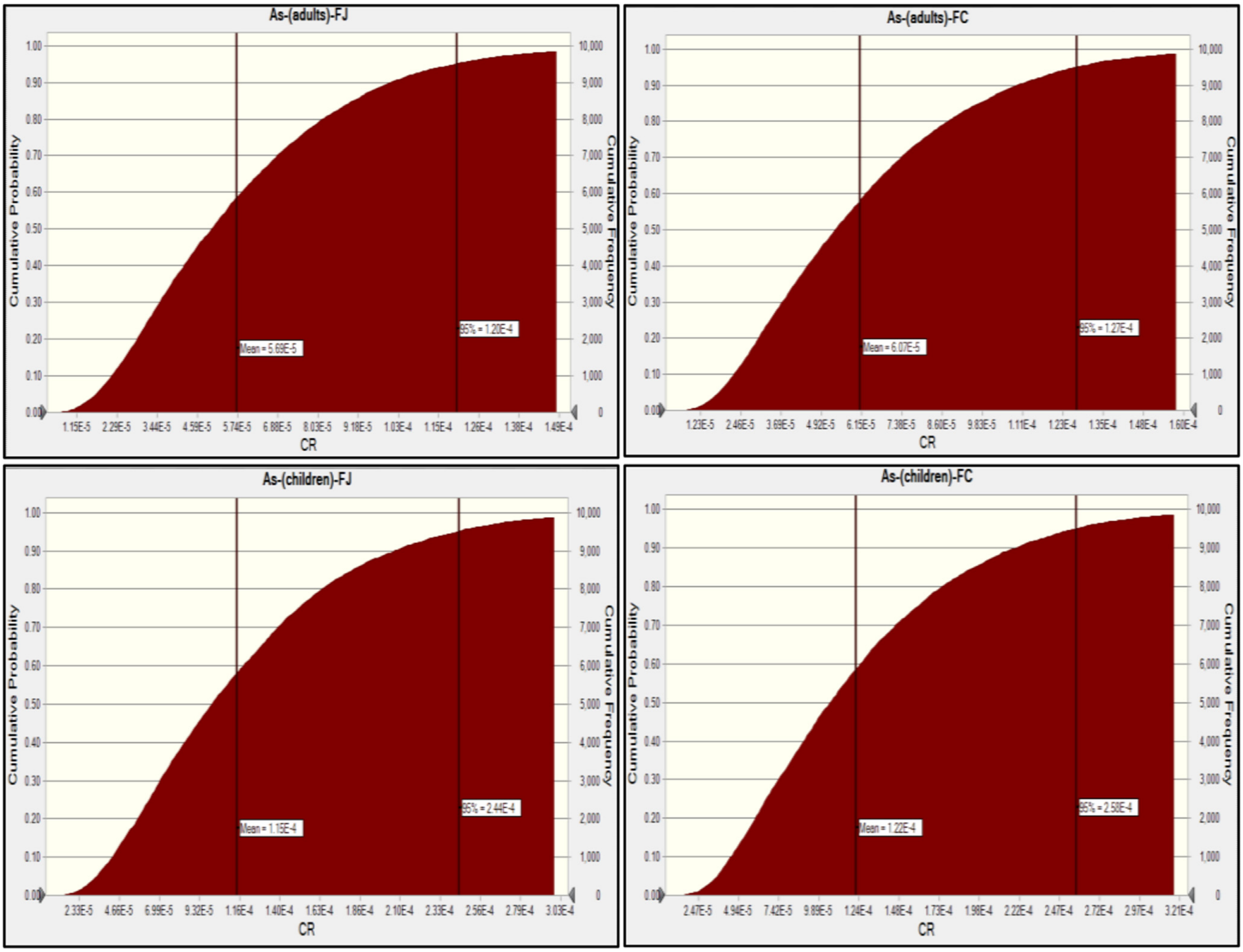

Fig. 9. Cancer risk (CR) in the adults and children due to fruit juice (FJ) and fruit canned (FC) content of As ingestion.

juices was noted. Also, the minimum concentration of heavy metals investigated was correlated to pineapple juice, while the maximum concentration of heavy metals was noted in the canned orange, cherry, and peach. The rank order of heavy metals measured in different kinds of fruit juices was arranged as Al > Sn > Pb > As > Cd > Hg, and for fruits canned this rank was Pb > Al > Sn > As > Cd > Hg. In most of the samples, heavy metals have been measured at lower levels than the standard limits. The health risk assessment via MSC indicted that rank order of heavy metal based on THQ was Al > Sn > As > Pb > Cd > Hg. THQ in the adults and children are at considerable non-carcinogenic risk due to Al and Sn (THQ > 1); Also, and carcinogenic risk due to As (CR > 1E-6) in both fruit juices and fruits canned. Therefore, it is necessary to carry out control plans such as HACCP to reduce the concentration of heavy metals in fruit juices and fruits canned in Iran.

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