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Research Article

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Determination of the content of selected trace elements in Polish commercial fruit juices and health risk assessment

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Abstract: The objective of the study was to determine the content of cadmium (Cd), lead (Pb), arsenic (As), aluminium (Al), thallium (Tl), antimony (Sb) and uranium (U) in the apple and orange juices and black currant nectar in relation to the kind of packaging. Also, probabilistic risk assessment (non-carcinogenic) was estimated by models including target hazard quotient (THQ and THQ*). Aluminium (Al) was present at the highest concentration in the analysed juices and nectars, with average concentration ranging from 1.34 mg/kg in orange juices (glass) to 4.26 mg/kg in black currant nectar (glass). Fruit juices and nectars kept in tetra pack packaging were characterised by elevated concentrations of Al and Sb, while the products in glass packaging contained significantly higher concentrations of As compared with the products in tetra pack packaging. Although the average concentrations of trace elements were lower than the standard limit, exposure to non-carcinogenic factors was demonstrated.

Keywords: trace elements, uranium, fruit juices, packaging, health risk assessment

1 Introduction

In recent years, an increase of interest in fruit and vegetable juices is observed in the world. This is due to

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Urszula Pankiewicz, Artur Mazurek: Department of Analysis and Evaluation of Food Quality, University of Life Sciences in Lublin, 8 Skromna Street, 20-704 Lublin, Poland increased consumer awareness in the aspect of search for the products rich in health-promoting components.

Juices are fully natural products, produced from healthy and ripe fruits and vegetables. They are obtained through juice expression from pulp or through mechanical rubbing. The nutritional value of juices is similar to that of the fruits from which they have been produced. Juices and nectars play an important role in human nutrition. They are sources of vitamins, especially vitamin C, folic acid and vitamins from group B, as well as minerals – mainly manganese and potassium but also phosphorus, magnesium, calcium, zinc and selenium. They contain fibre, which regulates the metabolic processes, as well as antioxidant and bioactive substances. In addition, they enhance the attractiveness of meals due to their pleasant taste, flavour, consistency and colour. In human diet, juices are an important source of water, which is an essential component for life. In addition, juices contain minerals, which are naturally present in the components in fruits and are related to the uptake of elements by plants from the natural environment (soil, water, air) [1]. Another factor to be considered is the effect of production conditions and packaging materials on the mineral contents in the readyfor-consumption product; hence, the materials that do not add undesirable components to enriching food should be selected as the packaging material [2,3].

An important aspect of the research on this kind of products is also one of the dietary proposals that juices should be the only kind of food products for a number of consecutive days in an entire diet programme. Therefore, given the significant contribution of fruit juices in the diet, research on health risk, which is associated with the presence of undesirable components in juices, is very important. An important component of food is trace elements, many of which have metabolic functions in humans (zinc, Zn; iron, Fe; copper, Cu; chromium, Cr; cobalt, Co), while other elements are toxic heavy metals (lead, Pb; cadmium, Cd; arsenic, As; mercury, Hg). Heavy metals have an impact on the bioavailability and metabolism of microelements; have neurotoxic, nephrotoxic,

carcinogenic and teratogenic effects; interfere with the functions of the cardiovascular system and the bone system and penetrate the blood-placenta barrier. Contamination with metals may even cause damage to the organisms, with death at a younger age [4]. It is of particular importance to conduct studies aimed at ensuring high quality of the consumed food, which will be safe to the consumers. Obviously, studies of this type are often limited to a specific kind of food products, which are common in a given geographical area. In Poland, apple juice and black currant nectar are the most popular products from the group of juices and nectars, in the case of which Poland is the leading producer of the apple juice and black current nectar on the world scale, and orange juice was produced from the imported fruits. Therefore, the objective of this study was to estimate the content of selected trace elements in commercial fruit juices with regard to the kind of packaging, with determination of the health risk assessment associated with the consumption of that assorted products.

2 Materials and methods

2.1 Experimental material and sample preparation

The commercial products (10 assortments for each kind of products and year of production is 2017) were analysed: apple and orange juices and black currant nectars, packed in glass bottles and in tetra pack packages, were obtained from various producers. Three samples of each kind of juices were taken for the analyses: portions of about 0.5000 g of juice were weighed directly into a Teflon vessel, 10 mL of 65% HNO₃ was added (Suprapur grade; Merck, Germany) and microwave mineralisation was performed (Mars 5, CEM Corporation, USA). A blank sample containing only the reagents was included in every mineralisation batch. The microwave mineralization was performed stepwise at 400 W and 363 K, at 800 W and 393 K and at 1,600 W and 483 K. The cooled digestion solution was then diluted to 50 mL using high-purity deionized water.

2.2 Determination of trace elements

The content of cadmium (Cd), lead (Pb), arsenic (As), aluminium (Al), thallium (Tl), antimony (Sb) and uranium (U) in the juice samples was determined with an inductively coupled plasma mass spectrometer

(ICP-MS, 820-MS; Varian, Mulgrave, Australia) with quadrupole mass analyser. The instrumental conditions for trace element determination by ICP-MS are as follows:

• Plasma: argon plasma

• Plasma flow: 18 L/min

• Auxiliary flow: 1.8 L/min

• Sheath gas flow: 0.12 L/min

• Nebulizer flow: 0.95 L/min

• Sampling depth: 6 mm

• Radio frequency (RF) power: 1.35 kW

• Pump rate: 6 rpm

• Stabilization delay: 35 s

• First extraction lens: 5 V

• Second extraction lens: 190 V

• Third extraction lens: 225 V

• Corner lens: 200 V

• Left mirror lens: 39 V

• Right mirror lens: 34 V

• Bottom mirror lens: 36 V

• Entrance lens: 1.00 V

• Fringe bias: -2.90 V

• Entrance plate: -39 V

All the certified single-element standard solutions used to prepare calibration curve $(1,000 \, \text{mg/L})$ were of highest purity grade (99.999%) and were supplied by Ultra Scientific. The calibration standards for ICP-MS analysis were prepared by diluting solutions in 1% HNO₃. Table 1 presents the contents of elements in the certified reference material TM 27.3.

Analysis of the reference material TM 27.3 using the applied analytical procedure with the ICP-MS technique demonstrated that the applied procedure allows to obtain correct quantitative results (parameter $E_{\rm n}$ < 1).

2.3 Health risk assessment

The health risk assessment (non-carcinogenic hazard) with regard to the presence of heavy metals in fruit juices was performed using the previously described model [5]. The target hazard quotient (THQ) was used for the calculation of non-carcinogenic hazard of ingestion of heavy metals (equation (1)) [1].

$$THQ = CDI/RfD, (1)$$

where the chronic daily intake (CDI) is the estimated amount of intake of heavy metals per kilogram of body weight and RfD is the reference dose of heavy metal oral

Mineral	Results declared by the manufacturer, $X (\mu g/L)$	The results of this study, x (μ g/L)	Uncertainty of CRM, U_{CRM} (%)	Uncertainty of the results received, U_{LAB} (%)	E _n *
Al	44.2 ± 5.0	46.4	11.3	4.6	0.4050
As	2.13 ± 2.13	3.1	13.1	32.9	0.9174
Cd	1.05 ± 0.11	1.2	10.5	14.7	0.7211
Sb	1.49 ± 0.17	1.8	11.4	17.3	0.8739
Tl	1.48 ± 0.21	1.8	14.2	17.8	0.8351
Pb	2.86 ± 0.29	2.6	10.2	14.8	0.5384
U	2.03 ± 0.18	2.5	8.8	19.2	0.9177

Table 1: The content of elements in the certified reference material (CRM) TM 27.3

*
$$E_{\rm n} = \frac{|x-X|}{\sqrt{U_{\rm LAB}^2 + U_{\rm CRM}^2}}$$
.

The coefficient E_n is the absolute value of the quotient of the obtained result (x) and the assigned CRM value (X) and the root of sum of both uncertainties.

 E_n , coefficient defining the correctness of results; $E_n < 1$, satisfactory result; $E_n > 1$, unsatisfactory result.

intake (mg/kg d). The RfD for cadmium (Cd), aluminium (Al), lead (Pb), arsenic (As), uranium (U), thallium (Tl) and antimony (Sb) is 0.0005, 0.0004, 0.0085, 0.0003, 0.0002, 0.00001 and 0.0004 mg/kg d, respectively [6].

The value of CDI was calculated using equation (2) [1].

$$CDI = (C \times IR_i \times EF_i \times ED_i)/(BW_i \times AT), \qquad (2)$$

where *C* is the trace element concentration in juices (mg/kg), IR_i is average daily consumption of juices in Poland (38 g/person/day), EF_i is exposure frequency (365 days/year), ED_i is exposure duration (70 years, equivalent to the average lifetime), BW_i is the average body weight (70 kg) and AT is the average exposure time for non-carcinogens (365 days/year \times ED = 25,550).

When THQ > 1, there is a probability of potentially harmful effects, and when THQ \leq 1, there is no probability of unfavourable effects [1].

To estimate the total target hazard quotient (TTHQ) of multiple heavy metals, the sum of THQ*i* for each heavy metal was estimated by equation (3) [1,6].

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

For an estimate, daily intake (EDI) was calculated using equation (4) [7].

$$EDI = (IR_i \times C)/BW_i, \tag{4}$$

where EDI is estimated daily intake (μ g analysed element/kg body weight/day), IR_i is average daily consumption of juices in Poland (38 g/person/day), C is

the trace element concentration in juices (mg/kg) and BW_i is average body weight (70 kg).

In addition, in the calculations of health hazard, the fruit juice portion at the level of 200 g, recommended by nutrition experts, was taken into account, which is considerably higher than the average consumption of fruit juices in Poland ($IR_i = 38 \text{ g/person/day}$), and the non-carcinogenic hazard THQ*, TTHQ* and the estimated daily intake EDI* for increased level of consumption of fruit juices were also determined in this manner.

2.4 Statistical analyses

Data were analysed using one-way ANOVA, followed by Duncan's test, using the SAS statistical system (SAS version 9.1; SAS Inst., Cary, NC, USA). The significance of all the tests was set at $p \le 0.05$.

Ethical approval: The research conducted is not related to either human or animal use.

3 Results and discussion

In all the analysed products, the presence of cadmium (Cd), lead (Pb), arsenic (As), aluminium (Al), thallium (Tl), antimony (Sb) and uranium (U) was detected. Aluminium (Al) was present at the highest concentration in the analysed juices and nectars, with average content from 1.34 mg/kg in orange juices (glass) to 4.26 mg/kg in black currant nectars (glass). Sobhanardakani et al. [8] demonstrated that the content of Al in commercial juices

in Iran varied from 0.10 mg/L in mango juice to 3.30 mg/L in cherry juice, and to 1.20 mg/L in orange juice. Velimirović et al. [9] reported that the content of Al in juices in Serbia varied from 14.55 mg/kg in peach juice to 91.01 mg/kg in black grape juice. Enani and Farid [10] demonstrated that the content of Al in juices from Saudi Arabia varied from 0.115 mg/L in mango juice to 0.144 mg/L in apple juice. Fathabad et al. [1] reported that in juices in Iran the range of Al concentration, as average in fruit juices, was 340.62 (65.17-1039.2) µg/kg. Savić et al. [11] report that the concentration of arsenic in seven orange juice samples in Serbia was in the range of 2.01-2.56 mg/kg. The level of Al in juices from Brazil ranged from 0.1 to 0.4 mg/L [12]. Al is the third most common element in the Earth crust [13] and can easily migrate to human through food. Al is characterised by its high neurotoxicity (Alzheimer's disease) and can accumulate in the brain, bones and liver [14,15]. There is evidence for neurodegenerative disturbance in the functioning of the kidneys as a result of chronic exposure to aluminium [16]. The intake of aluminium falls within the broad range of 10-100 mg daily, while according to FAO/ WHO, the tolerable intake of aluminium is 7 mg/kg of body weight per week, i.e. approximately 50 mg per day.

The content of arsenic (As) was at average levels from 0.03 mg/kg in apple juice (tetra pack) to 0.10 mg/kg in black currant nectar (glass). Fathabad et al. [1] reported that in juices in Iran the range of arsenic concentration, as average in fruit juices, was 3.76 (1.137–18.36) µg/kg. Savić et al. [11] reported that the concentration of arsenic in seven orange juice samples was in the range of 2.01-2.56 mg/kg. In another study, the authors observed that the As levels in juices in Romania varied from <0.001 to 4.36 µg/L [17]. Arsenic is a natural component of most soils, which results in its presence in the products of plant origin. Unfortunately, in certain parts of the world, e.g. Bangladesh, drinking water is a source of arsenic. Arsenic compounds find application as catalysts, bactericides, herbicides, fungicides, admixtures to animal feed, corrosion inhibitors, veterinary medicines, tanning agents and wood protection agents, and even were used as first medicine in the treatment of syphilis. The average human adult daily intakes little less than 1 g of arsenic from the natural environment. In humans, exposure to inorganic arsenic causes a disturbance in the functioning of the kidneys and liver, anaemia, a disturbance in the functioning of the alimentary tract and a decrease in body mass. The inorganic arsenic compounds were entered in the list of carcinogenic compounds [18].

In this study, the analysed commercial products were characterised by similar average levels of cadmium (Cd) and

lead (Pb) of approximately 0.01 and 0.02 mg/kg, respectively, irrespective of the way of packaging. Enani and Farid [10] demonstrated that the content of Cd and Pb in juices in Saudi Arabia varied from 1.07 (apple juice) and 2.00 µg/kg (orange juice) to 1.57 µg/kg (mango juice) and 2.64 µg/kg (apple juice), respectively. Fathabad et al. [1] reported that in Iran the range of concentration for Cd and Pb, as average in fruit juices, was 2.12 (0.89-3.44) and 40.86 (27.87-66.1) µg/kg, respectively. In another study, the authors noted that in juices from Romania, the Cd levels varied from 0.12 to $1.42 \,\mu g/L$ and the Pb levels varied from 1.02 to $75.68 \,\mu g/L$ [17]. In Iraq, the concentrations of Cd and Pb in juices were found to vary from 0.01 to 2.40 mg/kg and from 0.01 to 0.09 mg/kg, respectively [19]. Harmankaya et al. [20] noted stable levels of Cd in peach, orange, apricot and cherry juices, at approximately 0.01 mg/kg. Velimirović et al. [9] reported that the content of Cd in juices in Serbia varied from 0.018 mg/kg in black grape juice to 0.121 mg/kg in black cranberry juice. In another study on juices from Serbia, Savić et al. [11] demonstrated that the presence of Cd was detected in the samples at the concentrations from 0.01 to 0.05 mg/L, while in the case of lead, the highest observed concentration was 1.19 mg/L. In India, the content of Cd in juices was found to vary in the range from 0.002 to 0.009 µg/kg [21]. In 1993, cadmium and its compounds were declared as carcinogenic factors in humans by the International Agency for Research on Cancer (IARC). According to FAO/WHO recommendations, tolerable weekly intake of cadmium by an adult human is 0.4-0.5 mg, and the maximum allowable dose is $60-70 \,\mu g/day$ [22].

Hassan et al. [23], in products from Egypt, found the highest concentration of lead (Pb) in apple juice, at 1.20 mg/kg, while in guava juice, the level of Pb varied from 0.03 to 0.05 mg/kg, in orange juice from 0.03 to 0.07 mg/kg, in orange nectar from 0.12 to 0.18 mg/kg and in peach nectar from 0.02 to 0.20 mg/kg. In the EU countries, the maximum level of lead in food has been set by Regulation of the Commission (EC) No. 1881/2006 of 19.12.2006 and by Regulation of the Commission (EU) No. 420/2011 of 29th April, 2011 [24,25].

The average levels of antimony (Sb), thallium (Tl) and uranium (U) in the analysed juices and nectars are as follows: the average level of Sb varied from 8.48 μ g/kg (currant nectar, glass) to 14.4 μ g/kg (orange juice, tetra pack), and that of Tl varied from 7.11 μ g/kg (orange juice, tetra pack) to 8.52 μ g/kg (orange juice, glass), while the average content of U in the juices and nectars fell in the range from 3.56 μ g/kg (apple juice, glass) to 3.78 μ g/kg (currant nectar, tetra pack).

In the past, thallium salts were a common component of poisons against rodents [26]. Thallium compounds are strongly toxic. A characteristic symptom of thallium poisoning is hair loss preceded by blackening of hair follicles. Other symptoms including disturbances in digestion, pain and damage to the cardiovascular system were also observed.

Sb is an element which occurs mainly in coal deposits, especially lignite, and in heating oil and petrol. It is primarily produced by the combustion of coal and incineration of municipal waste. In clean water, its content usually does not exceed $1\,\mu\text{g/L}$. Generally, inorganic antimony compounds are more toxic than organic compounds, and $Sb(\pi)$ compounds are approximately 10-fold more toxic than Sb(v) compounds. In turn, the toxicity of antimony compounds is about 10-fold lower than that of arsenic compounds. Antimony as an element is more toxic than its salts. The biological role of antimony in living organisms is not fully elucidated. The IARC stated that there is sufficient evidence from research on animals to accept that Sb_2O_3 is a carcinogenic compound [18].

So far, many studies concerning the content of antimony (Sb), thallium (Tl) and uranium (U) in juices have not been conducted. There is also very little data on the content of U in food products. The European Food Safety Authority (EFSA) reports that the average content of U in fruit and vegetable juices was 0.30–1.33 µg/kg, with a maximum of 1.52–5.00 μg/kg; in bottled water, the average was $1.66-1.83 \,\mu\text{g/L}$ (maximum $152.70 \,\mu\text{g/L}$); in milk and dairy-based products, the average was 0.30-2.10 µg/kg (maximum 1.50-4.50 µg/kg) and in other products (miscellaneous), the average was 3.70-4.04 µg/kg (maximum 25.00 µg/kg) [27]. The maximum permissible level of uranium contamination in drinking water is 0.03 mg/L [28]. The maximum allowable concentration of uranium in water in Canada is 0.02 mg/L. In Australian regulations for drinking water [29], it is stated that the concentration of uranium in drinking water should not exceed 0.017 mg/L for health considerations. WHO [30] reports that uranium levels in drinking water are usually lower than 0.001 mg/L. Uranium concentrations at the level of 0.7 mg/L were measured in water in Canada. Concentrations exceeding 0.02 mg/L were noted in underground waters in a part of New Mexico and in central Australia. In Great Britain, a study of 8,062 samples of groundwaters revealed average concentration of uranium at the level of 0.0014 mg/L, with a maximum concentration of 0.07 mg/L [31].

In the analysis of the results concerning the content of elements in the analysed products, obtained in the study, the kind of packaging is also an important aspect. The study demonstrated that the kind of packaging significantly determined the content of aluminium (Al), antimony (Sb) and arsenic (As) (Figure 1). There are reports on studies that addressed the problem of the effect of the kind of packaging on the migration of an assayed element. Rodushkin and Magnusson [2] studied the migration of aluminium from aseptic tetra pack packages to orange juice stored for 12 months and found that the concentration of Al in the juices did not differ statistically significant from the initial sample (from 88.2 to 92.4 µg/L). The research demonstrated that the kind of packaging is of significant importance in the case of aluminium levels in food. Elevated levels of aluminium are observed, in particular, in products stored or packed in aluminium vessels or foils. The range of the migration depends on the kind of aluminium, pH, duration of contact with food and the presence of salt. Et [32] found the content of metals in commercial juices in various packaging in Pakistan: lead content of 0.098-1.061 mg/L (tetra pack), 0-0.116 mg/L (plastic bottle) and 0.363-0.754 mg/L (sachem pack), and cadmium content of 0-0.032 mg/L (tetra pack), 0-0.016 mg/L (plastic bottle) and 0.0091-0.249 mg/L (sachem pack). Hansen et al. [33] analysed the content of metals in commercial juices in various packaging - polyethylene terephthalate (PET) bottles, glass or Tetra Pak® cartons - and demonstrated the highest concentration of antimony in sour cherry juice in a glass bottle, at 13.6 µg/L. They reported that currant nectars were characterised by the highest levels of antimony.

Antimony trioxide is used as a polycondensation catalyst in the production of PET, which is used as a packaging material in the food industry [34]. Studies conducted to date indicate that antimony can migrate from packaging to food products, e.g. mineral water or citrus fruit juices [35]. The analysed products contained significantly less than 1 mg/L of antimony, which means that the measured levels of Sb were below the established safe limit for drinking water –6 mg/L [36].

In another study, the concentration of antimony in 47 samples of bottled water and in non-alcoholic drinks was in the range from 0.03 to 6.61 μ g/L, the allowable limit being exceeded in only one sample [37]. Fan et al. [3] studied the effect of temperature and storage time on the migration of antimony from PET bottles to drinking water and demonstrated that an increase in temperature contributes to an increase in Sb concentration in water.

The Canadian Food Inspection Agency [38] tested the content of antimony (years 2010–2011) in 185 samples of juices and 174 samples of water in various packaging (glass, PET, metal cans, tetra pack). Eight samples of juices in various packaging (glass, PET, metal can, tetra pack) had detectable levels of antimony in the range from 0.0038 to 0.0572 ppm, and one sample of water (PET) had Sb content of 0.0031 ppm.

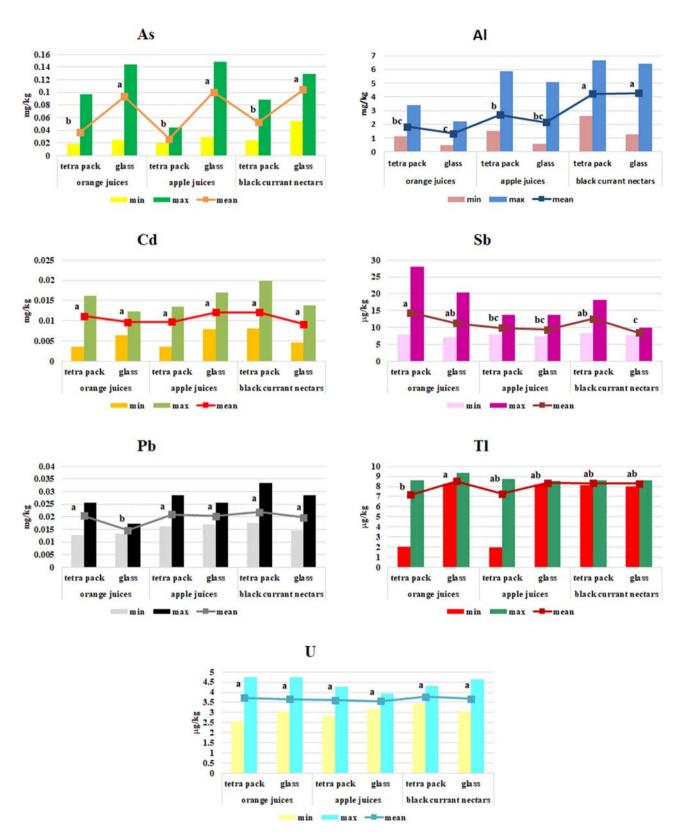


Figure 1: The contents of trace elements in the analysed juices with regard to the kind of packaging. Values designated with the same letters (a, b, c...) do not significantly differ at 5% error (Duncan's test).

4 Health risk assessment

4.1 Non-carcinogenic risk

The rank order of the THQ and THQ * of trace elements in fruit juices is as follows: aluminium (Al: from 2.152 to 5.756; from 11.329 to 30.293) > antimony (Sb: from 0.523 to 0.698;

from 2.753 to 3.672) > arsenic (As: from 0.116 to 0.143; from 0.610 to 0.752) > cadmium (Cd: from 0.109 to 0.120; from 0.571 to 0.629) > thallium (Tl: from 0.021 to 0.023; from 0.112 to 0.119) > uranium (U: 0.005; 0.027) > lead (Pb: from 0.002 to 0.003; from 0.012 to 0.014) (Table 3). Because the concentration of Al was higher than the concentration of other metals in fruit juices (Table 2) and its Rfd was also very low (0.0004 mg/kg d) [6], the THQ of aluminium was

Table 2: The contents of trace elements in the analysed juices and nectars

Sample code	Al (mg/kg)	As (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Sb (µg/kg)	Tl (µg/kg)	U (µg/kg)
Orange juices							
Tetra pack							
Brand 1	1.726bc	0.097bc	0.016ab	0.045ab	27.945a	8.632ab	4.748a
Brand 2	3.393a	0.020d	0.016a	0.045ab	9.715cd	8.222b	3.296ab
Brand 3	1.376c	0.025d	0.010c	0.051a	8.719cd	8.517ab	4.213ab
Brand 4	1.520bc	0.021d	0.010c	0.038bc	7.934cd	8.468ab	3.844ab
Brand 5	1.128cd	0.019d	0.004e	0.026d	17.720b	2.006c	2.556b
Glass							
Brand 6	2.209b	0.080c	0.012bc	0.034cd	20.480b	8.301ab	4.734a
Brand 7	2.170b	0.025d	0.010cd	0.031cd	8.048cd	8.358ab	3.057ab
Brand 8	1.189cd	0.099bc	0.011c	0.027d	9.709cd	8.286ab	3.162ab
Brand 9	0.687cd	0.144a	0.009cd	0.026d	7.185d	8.293a	4.140ab
Brand 10	0.462d	0.119ab	0.006de	0.027d	11.060c	9.344a	3.178ab
Mean	1.586	0.065	0.010	0.035	12.852	7.843	3.693
Apple juices							
Tetra pack							
Brand 11	5.875a	0.045d	0.014b	0.057a	11.692ab	8.710a	4.283a
Brand 12	2.038ed	0.020f	0.011bcd	0.039cd	7.980bc	8.544ab	3.571abc
Brand 13	2.379d	0.026ef	0.010cd	0.042bcd	8.048bc	8.500ab	3.748ab
Brand 14	1.621ef	0.023ef	0.010bcd	0.038cd	8.091bc	8.642a	3.652abc
Brand 15	1.509f	0.019f	0.004e	0.033d	13.719a	1.976c	2.818c
Glass							
Brand 16	2.898c	0.059c	0.017a	0.045bc	13.815a	8.545ab	3.627abc
Brand 17	1.341fg	0.030e	0.012bc	0.036cd	7.964bc	8.540ab	3.946ab
Brand 18	5.058b	0.118b	0.008d	0.034cd	8.623bc	8.239b	3.726abc
Brand 19	0.562h	0.147a	0.011bcd	0.038cd	7.332c	8.280b	3.168bc
Brand 20	0.893gh	0.149a	0.012bc	0.051ab	9.079bc	8.226b	3.328bc
Mean	2.417	0.064	0.011	0.041	9.634	7.820	3.587
Black currant n	ectars						
Tetra pack							
Brand 21	3.300cd	0.057ef	0.014b	0.039c	18.250a	8.621a	3.611cde
Brand 22	3.594c	0.025f	0.020a	0.067a	9.227de	8.165b	3.529cdef
Brand 23	2.628cd	0.024f	0.010d	0.038c	8.358ef	8.286ab	4.033bc
Brand 24	6.646a	0.071de	0.008e	0.035cd	16.253b	8.228ab	4.301ab
Brand 25	4.92b9	0.088cde	0.008e	0.041c	10.874c	8.304ab	3.423def
Glass							
Brand 26	5.332b	0.116abc	0.012c	0.057b	9.946cd	8.638a	3.750cd
Brand 27	5.916ab	0.055ef	0.008e	0.029d	7.646f	8.033b	3.113ef
Brand 28	6.409a	0.094bcd	0.007e	0.035cd	8.441ef	8.269ab	3.831bcd
Brand 29	2.394d	0.127ab	0.014b	0.039c	8.147ef	8.162b	4.636a
Brand 30	1.261e	0.129a	0.005f	0.038c	8.239ef	8.301ab	3.029f
Mean	4.241	0.079	0.011	0.042	10.538	8.301	3.726

Values designated with the same letters (a, b, c...) within column do not significantly differ at 5% error (Duncan's test).

higher than that of other trace elements. The TTHQ and TTHQ* after fruit juice ingestion range from 3.105 to 6.620, and from 16.341 to 34.844, respectively (Table 3). Fathabad et al. [1] also observed elevated THQ values for aluminium in the analysed Iranian fruit juices.

By analysing the above data, one should conclude that it is very important to conduct studies aimed at the estimation of the content of trace elements in food products that constitute a significant share in the diet and may have an effect on the health risk. Numerous studies confirm the toxic properties of certain metals that may migrate into food not only by natural pathways but also as a result of various treatments related to the production technology. Analyses concerning the contamination of Polish food indicate that an average Pole following the conventional diet intakes 20% lead (Pb), 40% cadmium (Cd) and 35% mercury (Hg) of the allowable weekly intake dose. The largest amounts of those metals, due to their content in the daily diet, originate from sources of plant origin [39].

Based on toxicological studies, limit levels are defined for residues of substances accumulating in living organisms, taking into account the index of acceptable daily intake (ADI), the index established by the Joint FAO/WHO Expert Committee on Food Additives

(JECFA) defining the provisional tolerable weekly intake or the tolerable weekly intake established by the EFSA in 2009. In 2010, the EFSA proposed a new index BMDL (Benchmark Dose Lower Confidence Limit) - the lowest doses that have a specific effect in humans. The effect of heavy metals on living organisms depends also on the kind of metal, its chemical form (e.g. elemental, inorganic, organic), duration of the process of contamination and the age and nutritional status of the consumer. It also needs to be mentioned that due to the negative effects of the heavy metals on humans, the regulatory agencies established the maximum norms and guidelines for industries and for the society. Such norms include the Norm Codex 193-19,956, amended in 2013, which defines the maximum levels of contaminants in various food products, similarly to the Regulation of the European Commission (EC) No. 1881/ 2006 [24].

5 Conclusions

The level of heavy metals measured in different kinds of fruit juices was ranked as Al > As > Pb > Cd > Sb > Tl > U.

Table 3: The health risk assessment associated with the consumption of juices

-	Al	As	Cd	Pb	Sb	Tl	U
THQ							
Orange juice	2.1524	0.1176	0.1086	0.0022	0.6977	0.0213	0.0050
Apple juice	3.2802	0.1158	0.1194	0.0026	0.5230	0.0212	0.0049
Black currant nectars THQ*	5.7556	0.1430	0.1194	0.0027	0.5721	0.0225	0.0051
Orange juice	11.3286	0.6191	0.5714	0.0118	3.6720	0.1120	0.0264
Apple juice	17.2643	0.6095	0.6286	0.0138	2.7526	0.1117	0.0256
Black currant nectars	30.2929	0.7524	0.6286	0.0141	3.0109	0.1186	0.0266
TTHQ							
Orange juice	3.1048						
Apple juice	4.0672						
Black currant nectars	6.6204						
TTHQ*							
Orange juice	16.3412						
Apple juice	21.4061						
Black currant nectars	34.8440						
EDI							
Orange juice	0.8610	0.0353	0.0054	0.0190	0.0070	0.0043	0.0020
Apple juice	1.3121	0.0347	0.0060	0.0223	0.0052	0.0043	0.0019
Black currant nectars	2.3023	0.0429	0.0060	0.0228	0.0057	0.0045	0.0020
EDI*							
Orange juice	4.5314	0.1857	0.0286	0.1000	0.0367	0.0224	0.0106
Apple juice	6.9057	0.1829	0.0314	0.1171	0.0274	0.0223	0.0103
Black currant nectars	12.1171	0.2257	0.0314	0.1200	0.0301	0.0237	0.0107

It was shown that the rank order of heavy metals based on THQ and THQ* was Al > Sb > As > Cd > Tl > U > Pb. The THQ and THQ* values of aluminium and the THQ* of antimony in the juices were considerably higher than 1. With regard to the current legal regulations concerning the permissible levels of toxic elements [24], no exceeded levels of the elements were noted. Although the average concentrations of the trace elements were below the standard limit, exposure to non-carcinogenic factors was demonstrated.

The packaging of food products can have an impact on the level of trace elements in juices. Fruit juices and nectars stored in tetra pack packaging were characterised by an elevated concentration of Al and Sb, while products in glass packaging had significantly higher concentrations of As compared with products in tetra pack packaging.

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