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ORIGINAL ARTICLE

ASSESSMENT OF CADMIUM AND LEAD CONTENT IN TOMATOES AND TOMATO PRODUCTS

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ABSTRACT

Background. Cadmium and lead are completely redundant in the human body and any amount of these elements ingested poses a risk of adverse health effects. In non-occupational exposure the highest amount of xenobiotics enters the body with food. Valued for their taste, universal culinary application and health benefits tomatoes and tomato products are consumed almost every day by a large proportion of society. In order to protect consumers' health it is very important to monitor cadmium and lead content in food products.

Objective. The aim of the study was the health assessment of cadmium and lead content in tomatoes and tomato products in relation to their acceptable maximum levels in the relevant legislation.

Material and methods. Fresh fruits of the tomato plant and tomato products (juices, purées, concentrates, sauces) were analysed. Heavy metal content (Cd, Pb) was determined by flameless atomic absorption spectrometry (AAS). Before the AAS determination the samples were subjected to pressure mineralisation using microwave energy.

Results. Cadmium and lead contents in the studied food products were within the allowed range (the maximum level of cadmium and lead contamination of tomatoes is 0.05 mg/kg and 0.1 mg/kg of fresh mass). The limit for cadmium was exceeded only in a canned tomato concentrate (0.064 mg/kg of fresh mass). The average cadmium content in raw tomatoes and tomato products was: 0.017 mg/kg fresh weight, and lead 0.021 mg/kg fresh weight.

Conclusions. Despite the low cadmium and lead contamination of the study samples of tomatoes and tomato products, it seems desirable to constantly monitor the content of these elements in food due to their ability to accumulate in the body and the risk of adverse health effects developing after many years of exposure, even to small doses.

Key words: *tomatoes, vegetable products, heavy metals, contamination*

STRESZCZENIE

Wprowadzenie. Kadm i ołów są całkowicie zbędne dla organizmu ludzkiego, każda ilość tych pierwiastków jaka zostaje przyjęta przez człowieka stwarza ryzyko wystąpienia niekorzystnych skutków zdrowotnych. W narażeniu pozazawodowym największa ilość ksenobiotyków trafia do organizmu drogą pokarmową. Pomidory oraz ich przetwory cenione za smak, uniwersalne zastosowanie w kulinariach, a także właściwości prozdrowotne są spożywane niemal każdego dnia przez dużą część społeczeństwa. Ze względu na zapewnienie bezpieczeństwa zdrowotnego konsumentów, niezwykle ważne jest monitorowanie zawartości kadmu i ołowiu w produktach spożywczych.

Cel badań. Celem pracy była ocena zawartości kadmu i ołowiu w pomidorach i przetworach pomidorowych w aspekcie zdrowotnym, w odniesieniu do maksymalnych dopuszczalnych limitów tych zanieczyszczeń w badanych produktach.

Materiał i metody. Analizie poddano świeże owoce pomidora zwyczajnego, a także ich przetwory (soki, przeciery, koncentraty, sosy pomidorowe). Zawartość metali ciężkich (Cd, Pb) oznaczono za pomocą bezpłomieniowej spektrometrii absorpcji atomowej (AAS). Przed analizą AAS próbki poddawano mineralizacji ciśnieniowej przy użyciu energii mikrofalowej.

Wyniki. Zawartość kadmu i ołowiu w badanych produktach mieściła się w zakresie wartości dopuszczalnych (maksymalny poziom zanieczyszczenia kadmem i ołowiem pomidorów wynosi 0,05 mg/kg i 0,1 mg/kg świeżej masy). Limit kadmu został przekroczony tylko w koncentracie pomidorowym w puszkach metalowych (0,064 mg/kg świeżej masy). Średnia zawartość kadmu w surowych pomidorach i produktach pomidorowych wynosiła: 0,017 mg/kg świeżej masy, a ołowiu 0,021 mg/kg świeżej masy.

Wnioski. Pomimo niewielkiego zanieczyszczenia badanych próbek kadmem i ołowiem, celowym wydaje się dążenie do stałego monitorowania zawartości tych pierwiastków w żywności, ze względu na ich zdolność do kumulacji w organizmie i możliwość wystąpienia niekorzystnych skutków zdrowotnych po wielu latach narażenia, nawet na małe dawki.

Słowa kluczowe: *pomidory, przetwory warzywne, metale ciężkie, zanieczyszczenie*

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INTRODUCTION

Tomatoes are one of the most popular vegetables among consumers. Their annual production dominates among that of vegetables produced in EU countries and totalled 21 million tonnes in 2015. According to Statistics Poland, a statistical agency of the Polish government, the annual tomato consumption per capita is approximately 10 kg, which has been a stable figure over the last 15 years [23, 26].

The large popularity of tomatoes is associated with their wide application in many dishes: raw tomatoes are added to salads and processed tomatoes are the base for juices, sauces, purées, concentrates or jams. An increase in consumer awareness of the role of proper nutrition in a healthy lifestyle has led to the introduction of new products with functional additives on the market in which tomato processing by-products are used [21].

Tomato processing makes it possible to preserve healthy nutrients during periods of limited access to fresh vegetables (the winter season). After processing tomatoes are characterised by better health properties than their raw counterparts due to higher bioavailability of lycopene present in these vegetables [29].

Lycopene is a red and orange pigment belonging to the carotenoid group and is one of the strongest antioxidants. Anti-cancer properties are attributed to tomatoes such as protection against cell damage as well as reduction of prostate, lung, breast and gastrointestinal cancer and leukaemia risk. Multiple studies also demonstrate that the consumption of lycopene-rich products reduces cardiovascular risk [4, 17].

Apart from lycopene, tomatoes are also a rich source of vitamins C, E, D, K, E, B1, B2, B3 and B6, folic acid, fibre, macro- and micronutrients (potassium, sodium, phosphorus, magnesium, calcium, iron, copper, zinc and manganese), phenolic acids, flavonoids and phytosterols [3, 24].

Apart from high nutritional value, food should primarily be safe, both in the microbiological and chemical sense. Pollution emitted from industry, transport and waste contribute to the deterioration of the environment, including soil, and, consequently, food. Heavy metals are particularly dangerous for human health. They are characterised by a long life and are not subject to degradation or decomposition, which makes them linger in the environment for many years [27].

Cadmium and lead are classified as heavy metals and are completely redundant in the human body; any amount of them which is ingested by a human poses a risk of adverse health effects. These elements have the ability to accumulate in the body, particularly in bone tissue, but also in solid organs such as the liver and kidneys, which take part in their detoxification [14, 18].

The high toxicity of heavy metals manifests itself primarily in damage to internal organs (liver, kidneys) or abnormalities in the nervous system, hematopoietic system (anaemia), bones and cardiovascular system (arterial hypertension) [22].

Heavy metal exposure can cause abnormalities in protein synthesis and ATP production, which can lead to disease, including cancer. The toxic effects of elements discussed in the present study on the body depend on their chemical form, solubility in body fluids and lipids as well as the duration of exposure and resistance of a given body [18].

Cadmium is classified by the International Agency for Research on Cancer (IARC) as a Group 1 human carcinogen and teratogen. It can also cause anaemia, calcium and vitamin D metabolism disturbances, iron, copper and zinc deficiencies as well as abnormal function of reproductive glands and the immune system [28].

The harmful effects of lead on the human body involve mainly the nervous system: neurological and psychological abnormalities, IQ decrease, memory deterioration, aggression, easy fatigue and muscle paralysis occur. Kidneys and the liver as well as the cardiovascular and respiratory systems become damaged. Lead also causes reproductive disorders, has toxic effects on the embryo and is probably carcinogenic to humans according to IARC (Group 2A) [15].

The consumption of food contaminated with heavy metals is the primary route of exposure for humans. It is estimated that lead and cadmium enter the human body with plant products in approximately 60% and more than 80%, respectively [19].

Tomatoes and tomato products are valued for their taste, fragrance and health benefits. As such, they constitute part of everyday diet of a large proportion of society. The determination of heavy metal content in products which are consumed frequently can help in the assessment of consumer exposure to these xenobiotics.

The aim of the study was the health assessment of cadmium and lead content in tomatoes and tomato products in relation to their acceptable maximum levels in the relevant legislation.

MATERIALS AND METHODS

The study material were tomato fruits (*Solanum lycopersicum* L.) and tomato products (juices, purées, concentrates, sauces). The products were purchased in a retail chain shop and at a local vegetable market. The studied tomatoes differed in terms of variety, method of cultivation (conventional or organic farming) and county of origin. Tomato products were selected for the study based on different levels of processing and types of packaging (glass jars, metal cans, carton). For unprocessed tomatoes, cadmium and lead content was assayed both in fresh and dry mass of the product. Table 1 presents detailed characteristics of the study material.

(raw) tomatoes were dried in a laboratory forced air circulation oven (UFP 500, Memmert, Germany) at 60ºC (preliminary drying for 2 hours) and then at 105ºC until solid mass was obtained. The dried material was ground using a laboratory vibration mill (LWM-s, Testchem, Poland). Samples prepared in this way were subjected to mineralisation according to the methodology described above; subsequently, cadmium and lead content was assayed. Blind samples were also analysed.

Table 1. Characteristics of the studied products

No	Product	Kind, variety, type	Country of origin	Form
1.	tomato concentrate	concentrate in a glass jar	Poland	fresh mass
2.	tomato concentrate	canned concentrate	Poland	fresh mass
3.	cherry tomato	cherry tomato, “Sasari” variety size 25–35 mm	Poland	dry mass
4.	cherry tomato	cherry tomato, “Sasari” variety size 25–35 mm	Poland	fresh mass
5.	small-fruited strawberry tomato	cherry tomato, “Sunstream” variety	Poland	dry mass
6.	small-fruited strawberry tomato	cherry tomato, “Sunstream” variety	Poland	fresh mass
7.	“Koralik” cherry tomato	organic cherry tomato	Poland	dry mass
8.	cherry tomato on a twig	cherry tomato on a twig size 15–40 mm	Poland	dry mass
9.	cherry tomato on a twig	cherry tomato on a twig size 15–40 mm	Poland	fresh mass
10.	“Ożarowski” pink tomato	pink tomato, “Ożarowski” variety	Poland	dry mass
11.	“Lima” tomato	“Lima” variety	Poland	dry mass
12.	orange tomato	“Blush Tiger”, organic tomato	Poland	dry mass
14.	mini plum tomato	“Vespolino” variety, size 20–30 mm	Poland	dry mass
15.	mini plum tomato	“Vespolino” variety, size 20–30 mm	Poland	fresh mass
13.	oblong plum tomato	“Romanella” variety	Poland	fresh mass
16.	oblong plum tomato	“Romanella” variety	Poland	dry mass
17.	large-fruited “Gargamel” tomato	“Gargamel” variety	Poland	dry mass
18.	“Jawor” tomato	organic tomato	Poland	fresh mass
19.	dried tomatoes with spices	dried tomatoes with spices (salt, garlic, oregano)	Turkey	dry mass
20.	dried tomatoes	organic dried tomato	Turkey	dry mass
21.	canned tomatoes	canned tomatoes (whole)	Greece	fresh mass
22.	tomato purée	tomato purée in a carton	Greece	fresh mass
23.	tomato juice	tomato juice, glass container	Poland	fresh mass
24.	tomato sauce	canned sauce	Poland	fresh mass
25.	tomato sauce (ketchup)	mild tomato sauce (ketchup), plastic container	Poland	fresh mass

The analysed products were subjected to pressure mineralisation using microwave energy (Magnum II microwave mineraliser, ERTEC, Poland). Heavy metal content (Cd, Pb) was determined by flameless atomic absorption spectrometry (AAS) using the SavantAA Sigma spectrometer (GBC, Poland) and the GF 3000 graphite furnace (GBC, Poland). Assays were performed at the following wavelengths: 228.80 nm for cadmium and 217.00 nm for lead. For every sample measurements were taken three times and the final result is the arithmetic mean of the three readings.

Due to the differences in water content between different tomato varieties, some of the study material was subjected to drying. Samples of unprocessed

Statistical analysis was performed on the results obtained using Microsoft Excel 2010 spreadsheet software; means and standard deviations were determined.

RESULTS

According to the Commission Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs (OJ L. 364, 20.12.2006, as amended) [7], the maximum level of cadmium and lead contamination of tomatoes is 0.05 mg/kg and 0.1 mg/kg of fresh mass, respectively.

Cadmium and lead content in raw tomatoes and tomato products was within the allowed range. The limit for cadmium (0.05 mg/kg of fresh mass) was exceeded only in a canned tomato concentrate (0.064 mg/kg of fresh mass), (Table 2).

The highest heavy metals content in products subjected to drying was found in the “Koralik” cherry tomato (cadmium: 0.071 mg/kg of dry mass; lead: 0.139 mg/kg of dry mass), “Lima” tomato (cadmium: 0.216 mg/kg of dry mass), an organic orange tomato (cadmium: 0.206 mg/kg of dry mass), “Gargamel” tomato (cadmium: 0.076 mg/kg of dry mass), dried tomatoes with spices from Turkey (0.055 mg/kg of dry mass) and organic dried tomatoes from Turkey (0.107 mg/kg of dry mass), (Table 3).

In order to compare the results regarding cadmium and lead content in products subjected to drying with the maximum contamination levels set in the Commission Regulation (EC) the results were converted to fresh mass (based on mean water content in a given product). After these calculations no product was found to have cadmium and lead levels exceeding the allowed values.

DISCUSSION

Vegetables with edible fruits, such as tomatoes, contain relatively the lowest amounts of heavy metals.

Table 2. Cadmium and lead content in raw tomatoes and tomato products, in mg/kg of fresh mass

No	Product	Cd	Pb
1.	tomato concentrate (glass jar)	0.034 ± 0.004	< LOQ
2.	tomato concentrate (can)	0.064 ± 0.003	0.005 ± 0.001
3.	cherry tomato	0.028 ± 0.035	0.020 ± 0.002
4.	small-fruited strawberry tomato	0.006 ± 0.001	0.018 ± 0.002
5.	cherry tomato on a twig	0.007 ± 0.001	0.014 ± 0.004
6.	mini plum tomato	< LOQ	0.022 ± 0.003
7.	oblong plum tomato	< LOQ	0.007 ± 0.001
8.	“Jawor” tomato (organic farming)	< LOQ	< LOQ
9.	canned tomatoes	0.006 ± 0.001	0.006 ± 0.001
10.	tomato purée	0.024 ± 0.004	< LOQ
11.	tomato juice	0.018 ± 0.003	< LOQ
12.	tomato sauce	0.008 ± 0.001	0.006 ± 0.001
13.	tomato sauce (ketchup)	0.013 ± 0.002	< LOQ

Explanatory notes:
The table shows mean values ± standard deviations; LOQ for Pb = 0.004 mg/kg; LOQ for Cd = 0.004 mg/kg

Table 3. Cadmium and lead content in tomatoes subjected to drying, in mg/kg of dry mass

No	Product	Cd	Pb
1.	cherry tomato	< LOQ	< LOQ
2.	small-fruited strawberry tomato	< LOQ	< LOQ
3.	“Koralik” cherry tomato (organic farming)	0.071 ± 0.004	0.139 ± 0.004
4.	cherry tomato on a twig	0.012 ± 0.004	< LOQ
5.	“Ożarowski” pink tomato	0.015 ± 0.002	< LOQ
6.	“Lima” tomato (organic farming)	0.216 ± 0.004	0.026 ± 0.002
7.	orange tomato (organic farming)	0.206 ± 0.012	0.031 ± 0.040
8.	mini plum tomato	< LOQ	< LOQ
9.	oblong plum tomato	< LOQ	< LOQ
10.	large-fruited “Gargamel” tomato	0.076 ± 0.004	0.087 ± 0.002
11.	dried tomatoes with spices	0.055 ± 0.002	< LOQ
12.	dried tomatoes (organic farming)	0.107 ± 0.005	< LOQ

Explanatory notes:
The table shows mean values ± standard deviations; LOQ for Pb = 0.004 mg/kg; LOQ for Cd = 0.004 mg/kg

However, considering frequent consumption of tomatoes by consumers, these vegetables can pose a health risk since heavy metals can accumulate in the body and adverse health effects can be delayed by many years [5].

The use of mineral fertilisers and crop protection products in organic farming is limited to a significant extent; therefore, foodstuffs coming from organic farming should contain lower levels of heavy metals compared to conventional farming. In their study, *Ilić* et al. [11] compared cadmium and lead contents in Greek tomatoes cultivated using traditional and organic farming. Organic vegetables contained less cadmium than the conventional ones, whereas no such relationship was observed for lead. It is worth emphasising the fact that the analysed tomatoes were characterised by very low levels of both metals: lead content did not exceed 0.014 mg/kg of fresh mass, while cadmium did not exceed 0.00027 mg/kg of fresh mass.

Compared to the study cited above [11], organic tomatoes from the present study contained relatively high levels of cadmium: from 0.071 to 0.206 mg/kg of dry mass, while the content of lead was between < 0.088 mg/kg of dry mass and 0.139 mg/kg of dry mass.

Cadmium and lead content in selected organic and conventional produce was also investigated in a study by *Staniek* et al. [25]. The analysed products included cherry tomatoes in which cadmium level was found to be 0.0833 mg/kg of dry mass (organic farming) and 0.0086 mg/kg of dry mass (conventional farming). Regardless of the type of production system lead content was very low (below the method's sensitivity threshold: < 0.0005 mg/kg of dry mass). The comparison of cadmium content in tomatoes from both farming systems revealed that organic vegetables were nearly 10 times more contaminated with this element than conventional ones [25].

In their study, *Bressy* et al. [6] evaluated the content of selected elements in tomatoes of different varieties and levels of plant maturity. Cadmium content was the highest in the "Italy" tomato variety, which were at the last stage of maturation (0.21 μg/g of dry mass); in the early stage of maturity cadmium level in this type of tomato was nearly 6 times lower (0.0362 μg/g of dry mass). The comparison of the studied varieties revealed that the Khaki tomato variety contained the least amount of cadmium (< 0.0092 μg/g of dry mass). Tomatoes at the early stage of maturity in the study by *Bressy* et al. [6] contained a lower amount of cadmium than at the final stage of maturity, except for "Cherry" tomatoes for which the level of cadmium at the early stage was 0.027 μg/g of dry mass, whereas at the final stage it was < 0.008 μg/g of dry mass; this figure was the same as that in the present study.

In addition, the "Italy" variety of tomatoes was cultivated in conventional as well as organic farming systems. In both types of farming the level of cadmium in tomatoes was lower at the early stage of maturity than at the final stage. Conventional vegetables were characterised by higher levels of the investigated elements than organic ones [6].

The content of trace elements, including cadmium and lead in tomato fruits was also analysed by *Kleiber* et al. [12]. Their study aimed to determine the relationship between manganese concentration in a nutrient solution used for tomato cultivation and the levels of heavy metals, among other substances. Cadmium was found to be present in the range of 0.38–0.41 mg/kg of dry mass regardless of the manganese concentration used in the nutrient solution, while lead levels were 0.833–0.908 mg/kg of dry mass. In comparison to the results of the present study regarding cadmium and lead content in tomatoes, the mean cadmium content was nearly 2 to 25 times lower, while lead content was 6 to 32 times lower.

Vegetables become contaminated with toxic elements not only as a result of using fertilisers which may contain heavy metals, but also due to the location of the farm. High plant contamination is found in industrialised areas, along busy transport routes and near human dwellings (low-altitude emissions, municipal pollution) [13].

Osma et al. [20] compared the content of selected elements in tomatoes cultivated in various regions of Turkey, in suburban and industrial areas, among others. Cadmium content fell in the range of 0.17 to 0.40 μg/g of dry mass, while lead content was between 4.31 and 5.51 μg/g of dry mass. The researchers note that depending on the region of cultivation, washing vegetables before consumption can reduce cadmium and lead contamination: more than 5 to nearly 42 times for cadmium and nearly 2 to almost 20 times for lead [20].

Adefemi and *Awokunmi* [1] found very high levels of cadmium and lead in tomatoes in their study. Cadmium content fell in the range of 3.8–4.4 mg/kg of dry mass, while lead content was between 9.0 and 9.6 mg/kg of dry mass.

Lead contamination has also been investigated for plant products originating from the Legnica and Głogów region, Poland, in which a copper foundry operates. Cereal grains (barley, wheat, triticale, rye), vegetables (tomatoes, carrots, beetroots, potatoes, cabbage, parsley root and leaves) and fruit (apples, pears) were analysed. The limits were not exceeded in tomato, carrot, beetroot, potato, cabbage, apple and pear samples. Excessive amounts of lead were found in cereal grains and parsley leaves (135% and 436% of the maximum level, respectively) [19].

Apart from environmental sources (air, water, soil), food can also become contaminated with toxic elements during technological processes or storage (packaging contamination). Canned foods are a group of products to which heavy metals can migrate from packaging. Canning is a very popular form of food storage due to a long shelf life without refrigeration. Canned foods are ideal as a basis for meal preparation away from home and on trips; canned foods are also resistant to damage during transport [16]. Research investigating heavy metal content in canned foods has been conducted in a city in northern Jordan, among other places, where the following products were analysed: tomato sauce (ketchup), string beans, carrot and pineapple juice. The mean cadmium content in tomato sauce was 0.49 mg/kg of dry mass and that of lead was 2.95 mg/kg of dry mass [16].

A study in Nigeria demonstrated the following heavy metal contamination levels in canned tomatoes: lead from 0.1301 to 0.1701 mg/kg of dry mass and cadmium from 0.0091 to 0.0115 mg/kg of dry mass [8]. In another study conducted in the same country cadmium concentration in a canned tomato concentrate was below the level of detection, while lead concentration was found to be between below LOQ and 0.68 mg/kg of dry mass [9].

In their study, *Al-Maylay* et al. [2] found that canned tomato concentrates contained between 0.0 and 0.23 mg/kg of dry mass of cadmium and between 86 mg/kg and 138 mg/kg of dry mass of lead [2].

The comparison of the results of different studies on heavy metal concentrations in canned foods indicates a high level of variability of cadmium and lead content in these products; this may be determined by the source of food itself, the type of material from which a can is produced, the type of material used to join different parts of a can (soldering) and the presence of rusting inside the can body [29].

In order to protect consumers' health safety it is of particular importance to monitor toxic element content in food products. The results of research assessing cadmium and lead contents in tomatoes and tomato products indicate a low health risk associated with consuming this group of foodstuffs.

Due to the ability of heavy metals to accumulate in the human body and cause adverse health effects many years after exposure, it is advisable to conduct further studies aiming to determine the magnitude of exposure to the elements discussed. Since any amount of heavy metals in food is a potential health hazard, it seems desirable to strive for the minimisation of their presence in food.

CONCLUSIONS

The analysed tomatoes and tomato products were characterised by cadmium and lead levels below the maximum values set in the relevant Commission Regulation (EC). The limit for cadmium was slightly exceeded only in a canned tomato concentrate.

In order to protect consumers' health it is desirable to monitor the levels of cadmium and lead in food products, particularly those which constitute part of everyday diet.

Conflict of interest

The authors declare no conflict of interests.

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