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Cadmium in herbal weight loss products as a health risk factor for consumers

Original Study

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Abstract

Introduction. Herbal weight loss remedies are produced from various plant species which could accumulate heavy metals from the environment. The consumption of contaminated herbal preparations could be a source of consumer exposure to toxic metals. The aim of the study was to evaluate the content of cadmium in selected herbal weight loss products available on the Polish market, to determine exposure of consumers to the heavy metal included in herbal infusions prepared from the studied products and the related health risk.
Materials and Methods. The study included 29 herbal weight loss products available on the Polish market. The content of cadmium in the analyzed dried herbs and herbal infusions was analyzed. Based on the obtained results, the exposure of consumers to cadmium and the related health risks were estimated.
Results. Cadmium concentration in dried herbs did not exceed the maximum allowable concentration.
Conclusions. The exposure of consumers of the most contaminated herbal infusions to cadmium could be equal to half of the reference dose, which is an acceptable exposure threshold.

Keywords

fibroblast growth factors • endocrine • metabolic disorders • obesity • mineral balance

1. Introduction

Consumers perceive the intake of dietary supplements as a rapid and easy way to reduce body weight without having to change the diet. The world market for dietary supplements offers a number of herbal remedies, including those that support weight loss [1, 2]. Such products are among the most popular dietary supplements available on the Polish market. They are ranked in eighth place among the most commonly chosen products of this type in Poland and account for approximately 4% of the domestic market for supplements [3]. The widespread use of dietary supplements results partly from the increase in consumer awareness of the influence of diet, absorbable vitamins, and micro- and macroelements on health. Advertisements and commercials for products that promise immediate weight reduction have an unquestionable impact. These products are a response to the expectations of today's society in terms of esthetics of external appearance [1, 2].

Herbal dietary supplements, which affect the process of weight loss, accelerate fat tissue reduction, cleanse the body of toxins, inhibit appetite, act as diuretics, regulate digestive processes, and reduce fat absorption [4]. The composition of raw materials of weight loss dietary supplements is considerably varied. Herbal mixtures containing such plants as couch grass rhizome (Graminis rhizoma), chamomile (Chamaemelum), white mulberry (Morus alba), field horsetail (Equisetum arvense), common dandelion (Taraxacum), or senna are the most frequently used to produce such supplements. Herbs can have a beneficial effect on the functioning of the human body. However, various toxic substances (e.g., toxic metals) are absorbed by these plants due to progressive environmental pollution. Such pollution is the main cause of heavy metal contamination of herbal plants that are used in the production of herbal remedies. Soil, which accumulates heavy metals, is an environmental element that plays a crucial role in cadmium contamination in plants [5, 6].

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The most significant sources of cadmium emissions in the environment include anthropogenic sources such as nonferrous metal ore mining and processing industries, energy and chemical industries, transport, landfill sites, and burning of fossil fuels. Natural sources of toxic metal emissions in the environment include forest fires and volcanic eruptions. The use of plant protection products and mineral fertilizers, especially phosphate fertilizers, as well as sludge from sewage treatment plants may also affect cadmium contamination of soil [7, 8].

Ingestion of contaminated food is the major source of cadmium intake for the general population. The food products with the highest contribution to cadmium exposure are the edible plants. The gastrointestinal absorption of cadmium in humans amounts to about 5% but may be increased in iron-deficient people and can reach 15–20% [9]. The research has shown that bioavailability of cadmium from drinking water and food is not significantly different in the gastrointestinal tracts of rodents. Therefore, there is probably little difference in the human bioavailability of cadmium in food and drinking water [10]. The human exposure to cadmium can cause various adverse health effects such as kidney dysfunction, bone effects (osteoporosis), lung diseases, and liver and reproduction disorders. In 1993, the International Agency for Research on Cancer (IARC) classified cadmium and cadmium compounds as group I human carcinogens. The long-term exposure to cadmium may be associated with incidence of various cancer types: breast, lung, prostate, testes, pancreas, and kidney cancers [11, 12, 13].

The aim of the study was to assess the content of cadmium in selected herbal weight loss products available on the Polish market in terms of exposure of consumers of herbal infusions from the analyzed products and the related health risk.

2. Materials and Methods

2.1 Characteristics and preparation of the study material

The study material included herbal weight loss products available on the Polish market. A total of 29 herbal preparations were analyzed, including 17 samples referred to as dietary supplements and 12 samples that were not enrolled in this group. Both dried herbs and the herbal infusion were analyzed for each herbal product. The preparations were characterized by a diverse composition and the manufacturer's brand (Supplementary Material 1).

To prepare representative samples, the dried mass was scattered from the analyzed herbal products, which was then thoroughly mixed. Next, 1 g of each dry mass was weighed using the analytical balance (Radwag PS 750/X). From the analyzed samples of the dried mass, an infusion was also prepared in a glass beaker with a volume of 500 ml. A sachet which contained the appropriate amount of the dried mass (as indicated by the manufacturer) was placed in the beaker. Boiling tap water (250 ml) was poured over the sachet. After brewing and cooling the infusion, 20 ml of the liquid was collected for assessment. The weights were prepared directly in Teflon vessels. Next, 10 ml of spectrally pure, concentrated nitric acid (65%) and 0.5 ml of hydrogen peroxide solution (30%) were added. In the next stage, the Teflon vessels with the samples were placed in Magnum II microwave mineralizers (Ertec, Poland). The samples were subjected to four-stage mineralization. In each mineralization stage, the process occurred at different values of pressure, temperature, and power. The total mineralization time was 10 minutes. After mineralization and cooling, the dried mass samples were poured into 25 ml graduated flasks through a funnel. However, the infusion samples were poured into 50 ml graduated flasks and then the flasks were filled with ultrapure water to the mark indicating the desired volume.

The determination of cadmium content was carried out using electrothermal atomic absorption spectrometry (ET-AAS; Savanta Sigma) with an automatic sample feeder (PAL3000) and a graphite furnace (GF3000; GCB; Australia). The result was the mean value obtained from 3 repetitions. Metal concentration in dried mass samples was calculated by dry matter and fresh matter in the case of the infusion.

Measurements were taken using atomization in a graphite furnace and background correction at wavelengths of 228.8 nm, lamp current intensity of 5.0 mA, and gap width of 1.0 nm, using an inert gas (argon).

2.2 Quality control and quality assurance

To create the calibration curve, the Certificate of Reference Material 1000 mg 1^{-1} Cadmium Matrix: 2% HNO_3 SPEX CertiPrep was used. To confirm the correctness of analytical measurements, the certified reference material for edible plants was used (Certificate of Certified Reference Materials NCS ZC73012 Cabbage) from China National Analysis Center for Iron & Steel. The limit of quantification (LOQ) of the method was 0.00035 mg/kg. The results of cadmium content below LOQ were not included in the health risk calculations.

2.3 Estimation of health exposure and risk to consumers

The exposure of consumers of herbal weight loss products to cadmium was calculated considering three exposure scenarios. The first one assumed that consumers drank one standard serving of infusion (250 ml/day), which corresponds to the volume of one glass. The second scenario assumed that consumers drank two servings of infusion (500 ml/day; two glasses). In turn, according to the third scenario, consumers drank three servings (750 ml/day; three glasses). The exposure was estimated for an adult with a body weight of 70 kg.

Calculations of the daily dose of exposure to cadmium were carried out using the following equation developed by the United States Environmental Protection Agency (US EPA):

$$\text{Dose} = \frac{\text{C x V}}{\text{BW}}$$

where: C stands for the concentration of the metal in the sample (mg/L), V is the volume of the infusion consumed per day (L/day) and BW is the body weight of the exposed individual (70 kg).

The health risk of consumers of herbal weight loss products resulting from the exposure to cadmium was assessed by calculating the hazard quotient (HQ) [3] using the following equation:

$$\text{HQ} = \frac{\text{dose}}{\text{RfD}}$$

where the reference dose (RfD) for cadmium is 1 µg/kg/day [14].

It is assumed that if the HQ is higher than or equal to 1 (HQ ≥ 1), the amount of exposure is associated with a significant risk of adverse health effects under conditions of chronic exposure. However, if HQ < 1, the amount of estimated exposure is not a significant health hazard [3].

2.4 Statistical analysis

The Mann-Whitney U test and Wilcoxon matched-pairs tests were used for statistical analysis, assuming the significance of the results at the level of $p < 0.05$, using Statistica 13.0 Software from StatSoft Poland.

3. Results

3.1 Cadmium concentration in the analyzed samples of the dried mass and infusion

The mean concentration of cadmium in the samples of dried mass was 0.11 mg/kg dry matter (Table 1). Cadmium concentration lower than LOQ was found in 5 samples. It was slightly higher in food supplements than in other herbal products (0.10 - 0.11 mg Cd/kg dry matter). In the group of supplements, the highest cadmium concentrations were found in samples number 6 and 3 (± 0.24 mg Cd/kg dry matter) whose main components included yerba mate (Ilex paraguariensis), fennel (Foeniculum vulgare), peppermint (Mentha piperita), anise (Pimpinella anisum), cumin (Cuminum cyminum), hibiscus (Hibiscus), dandelion (Taraxacum), field horsetail (Equisetum arvense), nettle (Urtica dioica), and L-carnitine. In the case of herbal products which were not registered as dietary supplements, sample number 28 was the most contaminated (0.287 mg Cd/kg dry matter). It contained the following ingredients: field horsetail (Equisetum arvense), dandelion (Taraxacum), chamomile (Chamomilla recutita), com-

Table 1. Cadmium concentration in the samples of dried mass of herbal weight loss products (mg Cd/kg dry matter)

Sample no.	Manufacturer	Cadmium concentration (mg Cd/kg dry matter)
1	I	0.09
2	II	0.11
3	III	0.24
4	IV	0.12
5	V	0.08
6	VI	0.24
7	VII	0.16
8	VIII	0.08
9	IX	0.08
10	X	0.09
11	XI	0.11
12	XII	0.09
13	XII	0.04
14	VII	0.02
15	XIV	< LOQ
16	XV	< LOQ
17	XVI	< LOQ
18	XVII	0.09
19	XVIII	0.09
20	XIX	0.08
21	XX	0.14
22	XXI	0.15
23	XXII	0.09
24	XXIII	< LOQ
25	XXIV	< LOQ
26	XXV	0.04
27	XXVI	0.04
28	XXVII	0.29
29	XXVIII	0.01

Samples	N	Concentration range (min-max)	Mean concentration ± standard deviation
Dietary supplements	17	< LOQ – 0.24	0.11 ± 0.06
Other herbal products	12	< LOQ – 0.29	0.10 ± 0.08
Herbal weight loss products (in total)	29	< LOQ – 0.29	0.11 ± 0.07

mon knotgrass (Polygonum aviculare), and birch leaves (Betulae folium). The composition of the tested herbal products has been shown in Supplementary Material 1.

Among the herbal infusions, cadmium concentration lower than LOQ was found in 7 samples. The mean cadmium concentration in all infusions was 0.025 mg Cd/L (Table 2). Cadmium concentration did not exceed the maximum allowable concentration in any infusion [15]. The mean concentration of the metal was almost twice as high in the infusions from the products registered by manufacturers as dietary supplements (0.030 mg Cd/L) than in the infusions from other herbal remedies (0.017 mg Cd/L). However, no statistically significant differences of cadmium content were found between infusions from dietary supplements and the other herbal remedies ($p > 0,05$), probably because of the high differences between the concentration values of the compounds in the studied products groups. The infusion whose components included hibiscus, dandelion, field horsetail, nettle, and L-carnitine was the most contaminated with cadmium (0.045 mg/L). The lowest concentration of cadmium was found in the following infusions: 3a, 6a, 7a and 11a (0.001-0.002 mg/L), which are herbal products that are not registered as dietary supplements. The most important ingredients of these products were the following herbs: hibiscus (Hibiscus), dandelion (Taraxacum), field horsetail (Equisetum arvense), nettle (Urtica dioica), and L-carnitine; yerba mate (Ilex paraguariensis), fennel (Foeniculum vulgare), peppermint (Mentha piperita), anise (Pimpinella anisum), cumin (Cuminum cyminum), bladder wrack (Fucus vesiculosus), mulberry (Morus), rowanberry (Sorbus aucuparia), Pu-erh tea, green tea, rosehip (Rosa canina), Garcinia cambogia extract, and wild pansy (Viola tricolor) (Supplementary material 1). The statistical analysis showed that the mean cadmium content in

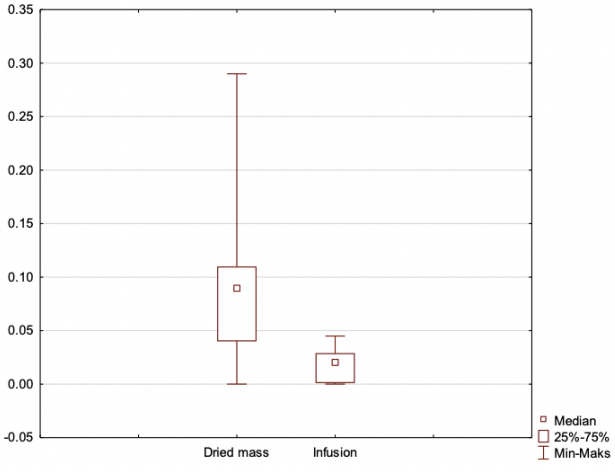


Fig. 1. The mean content of cadmium in the samples of dried mass and infusions of herbal weight loss products (mg Cd/kg dry matter / mg Cd/L infusions)

Table 2. Cadmium concentration in the samples of the herbal weight loss infusions (mg Cd/L)

Sample no.	Manufacturer	Cadmium concentration (mg Cd/L)
1a	I	0.039
2a	II	0.024
3a	III	0.045
4a	IV	0.029
5a	V	0.023
6a	VI	0.038
7a	VII	0.041
8a	VIII	0.014
9a	IX	0.036
10a	X	0.026
11a	XI	0.041
12a	XII	0.030
13a	XII	0.003
14a	VII	< LOQ
15a	XIV	< LOQ
16a	XV	< LOQ
17a	XVI	< LOQ
18a	XVII	0.023
19a	XVIII	0.020
20a	XIX	0.027
21a	XX	0.020
22a	XXI	0.024
23a	XXII	0.020
24a	XXIII	< LOQ
25a	XXIV	< LOQ
26a	XXV	< LOQ
27a	XXVI	0.001
28a	XXVII	0.017
29a	XXVIII	0.002

Samples	N	Concentration range (min-max)	Mean concentration ± Standard deviation	Maximum allowable concentration
Dietary supplements	17	< LOQ – 0.045	0.030 ± 0.012	1.0*
Other herbal products	12	< LOQ – 0.027	0.017 ± 0.009	
Herbal weight loss products (in total)	29	< LOQ – 0.045	0.025 ± 0.012	

**EC 2006 [4]*

samples of the dried mass was statistically significantly higher than in samples of herbal infusions (p<0,000018) (Figure 1).

3.2 Assessment of exposure of consumers of herbal weight loss products to cadmium

The exposure of consumers of weight loss products to cadmium was assessed. Exposure assessment showed that the mean daily oral intake of cadmium by consumers of herbal weight loss products ranged from 0.09 to 0.27 μg Cd/kg/day, depending on the exposure scenario. The mean exposure of consumers of herbal dietary supplements in each scenario (0.107-0.321 μg Cd/kg/day) was higher than the mean exposure of consumers of other herbal products (0.061-0.182 μg Cd/kg/day). The oral intake of cadmium by consumers who consumed three standard servings of a herbal weight loss product ranged from 0.011 to 0.482 μg Cd/kg/day. The consumers of products of manufacturers III, VI, VII and XI were the most exposed to cadmium. The lowest intake of cadmium was found in consumers of products of manufacturer XXVI (Table 3).

3.3 Estimation of the health risk of consumers of herbal weight loss products

Estimation of health risk did not show exposure of consumers to cadmium that would be high enough to be related to a significant health risk in any scenario. The estimated HQ for consumers of all herbal weight loss products was lower than 1. Increase of daily consumption of infusions is associated with a higher exposure to cadmium from herbal products. This also translated into higher HQ. According to the third exposure scenario, which assumed the consumption of three servings of the herbal infusion per day, the mean HQ was 0.27 for all analyzed products. The mean HQ was 0.18 in the case of products which were not classified as dietary supplements. In turn, it was 0.32 for dietary supplements in the third exposure scenario (Table 4).

The maximum value of hazard quotient among the estimated exposure scenarios was HQ = 0.48. This calculation has been carried out in the case of consumption of three servings of infusion (3a) from the product of the manufacturer III. The HQ higher than 0.4 was also found for consumers of the products of manufacturers I, VI, VII, and XI. The products of these manufacturers were registered as dietary supplements. In the group of products that are not dietary supplements, the highest health risk for consumers was found for the product of manufacturer XIV (HQ=0.29) (Table 4).

4. Discussion

The study found a similar contamination of dried mass of herbal weight loss products that were registered as dietary supplements compared to other analyzed herbal weight loss preparations. The latter group included products registered as foods intended for particular nutritional uses (e.g., dietary foods for special medical purposes and foods for people with carbohydrate metabolism disorders) and products introduced to the market as food that have not been classified yet as foods intended for particular nutritional uses or dietary supplements. The dietary supplements and the other herbal preparations are not medicines and therefore they are not subject to the same testing, manufacturing, and labeling standards and regulations as drugs. For this reason such products present a chance to pose a health risk for consumers because of contamination with heavy metals.

In the study, the presence of cadmium was found in the dried mass of most herbal preparations, which confirms the bioavailability of cadmium to plants [16]. Furthermore, despite the fact that cadmium is absorbed from the soil mainly by the root system of the plants, the metal is frequently accumulated in the upper parts of plants (i.e., seeds, leaves, inflorescences) [17], which are often used for the production of herbal remedies.

From the perspective of consumer exposure to heavy metals, their concentration in the infusion is of crucial importance. In the study, cadmium was found in most herbal infusions regardless of whether they were classified as dietary supplements. The products whose main ingredient was hibiscus were the herbal remedies with the highest cadmium concentrations (Supplementary material 1). Literature data confirm that hibiscus is predisposed to accumulate cadmium. As a result, the plant can be used in the process of phytoremediation of soils contaminated with heavy metals [18]. Although the above studies used another species of hibiscus (Hibiscus cannabinus), Hibiscus syriacus is used for the production of herbal remedies. However, both species belong to the same genus and show similar physiological properties.

Some herbal mixtures whose main ingredient was yerba mate or bladderwrack were also among the remedies (infusions) which were most heavily contaminated with cadmium. The former plant is a bush from South America. Its leaves are used to prepare a tea known as mate. Barella et al. reported that one of the highest concentrations of heavy metals was found in dietary weight loss supplements containing yerba mate [19]. The source of cadmium in herbal leaves may be related to artificial fertilizers, plant protection chemicals containing the metal, and possible contamination of soils caused by industrial activities, as in the case of tea leaves [20, 21, 22]. The latter plant (bladderwrack) is a brown alga which occurs, for instance, in the Baltic Sea.

Since algae, including bladderwrack, have a high capacity to accumulate heavy metals [23], the quality of the environment from which they are obtained is of great importance. Cadmium contamination of water reservoirs may contribute to the high content of this metal in algae-based herbal products. Compared to other dietary supplements, a threefold higher value of maximum allowable concentrations of cadmium in the products

Table 3. Exposure of consumers of herbal weight loss products (infusions) to cadmium depending on the exposure scenario (µg Cd/kg/day)

Sample no.	Dose µg Cd/kg/day		
	Exposure scenario		
	1	2	3
1a	0.139	0.279	0.418
2a	0.086	0.171	0.257
3a	0.161	0.321	0.482
4a	0.104	0.207	0.311
5a	0.082	0.164	0.246
6a	0.136	0.271	0.407
7a	0.146	0.293	0.439
8a	0.050	0.100	0.150
9a	0.129	0.257	0.386
10a	0.093	0.186	0.279
11a	0.146	0.293	0.439
12a	0.107	0.214	0.321
13a	0.011	0.021	0.032
14a	-	-	-
15a	-	-	-
16a	-	-	-
17a	-	-	-
18a	0.082	0.164	0.246
19a	0.071	0.143	0.214
20a	0.096	0.193	0.289
21a	0.071	0.143	0.214
22a	0.086	0.171	0.257
23a	0.071	0.143	0.214
24a	-	-	-
25a	-	-	-
26a	-	-	-
27a	0.004	0.007	0.011
28a	0.061	0.121	0.182
29a	0.007	0.014	0.021

showed higher cadmium concentrations in dietary supplements which contained algae-based products [15].

The content of heavy metals in herbal infusions is influenced by the level of contamination of the dried mass and the composition of the herbal mixture. The pH of the infusion is an additional determining factor. It has been shown that the acidification of the solution significantly increases the migration of metals from the dried mass to the infusion: for instance, as a result of adding citric acid to tea infusions [24]. It was found that the brewing time may also affect the level of cadmium extraction from the tea infusion. Sedrowicz et al. showed that the highest cadmium concentration was reached after 20 minutes of brewing [25].

In the present study, the estimation of the exposure of consumers of herbal weight loss products to cadmium was also conducted. The study considered three exposure scenarios for adults who consumed one to three standard servings per day. The amount of exposure to cadmium, and thus the health risk to consumers, increased with the increase in the consumption of herbal products. None of the herbal remedies under study provided the body with a sufficiently high dose of cadmium to create a significant health risk (HQ > 1).

In the case of the consumption of the most contaminated infusion, consumer exposure to cadmium accounted for approximately 50% of the reference dose. However, when four consecutive herbal products were consumed, the estimated exposure exceeded 40% of the safe exposure threshold. The results should be considered alarming because herbal weight loss products are only a supplement to the all-day diet. In general, herbal products are not regarded as the most important sources of human exposure to heavy metals. The highest doses of these products are delivered to the body by vegetables and cereal products [26]. This problem is particularly important in the cadmium-contaminated areas caused by industrial activity (e.g., the Silesian Province). It has been estimated that the consumption by the inhabitants of this region of only a few species of vegetables grown in the arable land located in the central part of the Silesian Province may be associated with a sufficiently high foodborne exposure

	N	Exposure scenario					
		1		2		3	
		Range (min-max)	Mean exposure of consumers ± Standard deviation	Range (min-max)	Mean exposure of consumers ± Standard deviation	Range (min-max)	Mean exposure of consumers ± Standard deviation
Dietary supplements	17	0.011 - 0.161	0.107 ± 0.043	0.021 - 0.321	0.214 ± 0.086	0.032 - 0.482	0.321 ± 0.129
Other herbal products	12	0.004 - 0.096	0.061 ± 0.033	0.007 - 0.193	0.121 ± 0.066	0.011 - 0.289	0.182 ± 0.100
Herbal weight loss products (in total)	29	0.004 - 0.161	0.089 ± 0.045	0.001 - 0.321	0.179 ± 0.090	0.011 - 0.482	0.268 ± 0.134

No data

Table 4. Health risk for consumers due to exposure to cadmium in herbal loss weight infusions according to specific exposure scenarios

Sample no.	Hazard Quotient (HQ)		
	Exposure scenario		
	1	2	3
1a	0.139	0.279	0.418
2a	0.086	0.171	0.257
3a	0.161	0.321	0.482
4a	0.104	0.207	0.311
5a	0.082	0.164	0.246
6a	0.136	0.271	0.407
7a	0.146	0.293	0.439
8a	0.050	0.100	0.150
9a	0.129	0.257	0.386
10a	0.093	0.186	0.279
11a	0.146	0.293	0.439
12a	0.107	0.214	0.321
13a	0.011	0.021	0.032
14a	-	-	-
15a	-	-	-
16a	-	-	-
17a	-	-	-
18a	0.082	0.164	0.246
19a	0.071	0.143	0.214
20a	0.096	0.193	0.289
21a	0.071	0.143	0.214
22a	0.086	0.171	0.257
23a	0.071	0.143	0.214
24a	-	-	-
25a	-	-	-
26a	-	-	-
27a	0.004	0.007	0.011
28a	0.061	0.121	0.182
29a	0.007	0.014	0.021

to cadmium to pose a significant health hazard [27, 28]. Therefore, providing the organism with additional doses of cadmium in herbal infusions (which in most cases are not necessary for the proper functioning of the organism and result from striving for slimness) significantly increases the risk of adverse health effects caused by the toxic and carcinogenic metal.

In the context of the results of the study, which indicate the possibility of cadmium contamination of some herbal weight loss products, which significantly increases the health risk for consumers, it is essential to take appropriate prophylactic measures. The responsibility for the health safety of consumers lies largely with the manufacturers of such products, who should pay attention to the source of the raw materials used for the production of herbal remedies and their quality. Mixtures should be randomly inspected for heavy metals and other common contaminants such as plant protection chemicals. Studies should be combined with health risk assessment of potential consumers. Manufacturers must be aware which components of herbal products may potentially be the most important source of their contamination.

On the other hand, consumers themselves should be more cautious when deciding to use such herbal products. The ideal solution would be to consult a family physician who would assess whether the use of a particular product is beneficial or whether the patient could experience adverse effects (e.g., herb-drug interactions). Furthermore, it is important for consumers to be aware of the possibility of contamination of heavy metals in herbal products. There is a possibility of accumulation of doses due to exposure related to the consumption of food and the use of herbal products even in the case of concentrations that do not pose a health risk.

Unfortunately, individuals choose such products due to aggressive advertisements and commercials for herbal weight loss products, as well as the image of a slim figure created by the mass media. Therefore, it is warranted to introduce more restrictive legal regulations that could impose greater obligations on the manufacturers of herbal products in terms of en-

	Hazard Quotient (HQ)						
	Exposure scenario						
		1		2		3	
	N	Range (min-max)	Mean	Range (min-max)	Mean	Range (min-max)	Mean
Dietary supplements	17	0.011 - 0.161	0.107	0.021 - 0.321	0.214	0.032 - 0.482	0.321
Other herbal products	12	0.004 - 0.096	0.061	0.007 - 0.193	0.121	0.011 - 0.289	0.182
Herbal weight loss products (in total)	29	0.004 - 0.161	0.089	0.007 - 0.321	0.179	0.011 - 0.482	0.268

No data

suring the health safety of such products. On the other hand, both physicians and pharmacists should instruct patients more about the potential health risks associated with uncontrolled use of herbal products, including those resulting from excessive exposure to heavy metals. Therefore, it is advisable to conduct training courses dedicated to health care workers in this respect to broaden their knowledge so that they could use it in their contact with patients.

5. Conclusions

The content of cadmium in herbal weight loss products did not exceed the maximum allowable concentration. The exposure of consumers of the most contaminated herbal infusions to cadmium could be even equal to half of the reference dose, which is an acceptable exposure threshold. To ensure consumer health safety, manufacturers of herbal weight loss products should pay more attention to the quality of the raw materials, whereas consumers should be aware of possible health hazards arising from the use of such products.

Abbreviations

BW - the body weight; C - the concentration of the metal in the sample; Cd – cadmium; ET -AAS - the electrothermal atomic absorption spectrometry; HQ - hazard quotient; IARC -International Agency for Research on Cancer; LOQ - The limit of quantification; *p*-value, probability value; RfD - the reference dose; V - the volume of the infusion consumed per day

Authors' Contribution

G.D.: supervising the project, writing: original draft preparation, research concept and design, final proofreading and approval of the version for publication; D.K.: research concept and design, data analysis and interpretation, writing: original draft preparation, carrying out the experiments, visualization, acquisition of data; D.R.: carrying out the experiments, literature review, writing: original draft preparation, visualization; J.D.: writing: review and editing.

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Conflict of Interest

The authors have no potential conflicts of interest to declare.

Ethics Approval

Due to the nature of the research, the consent of the ethics committee was not required.

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