Cadmium in Herbal Weight Loss Products as a Health Risk Factor for Consumers

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Abstract

Herbal weight loss remedies are produced on the basis of 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 in terms of exposure of consumers to the heavy metal included in herbal infusions prepared from the studied products and the related health risk. 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. On the basis of the obtained results, the exposure of consumers to cadmium and related health risk were estimated. Cadmium concentration in dried herbs 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. The total health risk of consumers resulting from the dietary exposure to cadmium could be high because the analyzed herbal products are not the essential part of the total diet.

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 of 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 on the eighth place among the most commonly chosen products of such type in Poland and account for approximately 4% of the domestic market of supplements [3]. The widespread use of dietary supplements results partly from the increase in consumer awareness related to the influence of diet, absorbable vitamins, micro- and macroelements on the health condition. Advertisements and commercials of such products that promise immediate weight reduction clearly 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 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].

The most significant sources of cadmium emission to the environment include anthropogenic sources such as non-ferrous metal ore mining and processing industries, energy and chemical industries, transport, landfill sites, and burning of fossil fuels. Natural sources of toxic metal emissions to 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].

A number of factors influence the bioavailability of toxic metals from soil to plants. The first of them is the soil reaction (pH). It has been shown that cadmium accumulation in plants is the highest in acidic soils. The composition of organic matter (OM) in the soil is also among the factors determining the bioavailability of metal ions. In soils rich in OM, metal compounds are associated with humus components and organic acids. The metals are then less mobile and less bioavailable to plant root systems. When soils are poor in OM, metal ions are absorbed by plants much more easily [9].

The plant species has also an influence on absorption of metals by plants. There are some varieties of plants that accumulate significantly larger amounts of metals compared to other plants. Furthermore, the plant species and the type of a metal have an impact on the location of accumulation of a given metal in a plant, e.g., in the root, leaves, seeds, or in the stem. As indicated by the literature data, factors such as age, plant species, and time of leaf harvest (young or mature leaves) have also an influence on the content of heavy metals in tea leaves apart from the type of soils, their level of contamination and the sources of metal emission to the environment [10, 11, 12]. In the case of edible plants, including those used for the production of herbal preparations, the above-mentioned aspects may affect the degree of contamination of the products introduced to the market. As a result, this translates into the amount of consumer exposure to toxic metals and their health risk.

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.

Material And Methods

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 in each herbal product. The preparations were characterized by a diverse composition and the manufacturer's brand (Supplementary Material I).

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 weighted 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. The sachet was poured with 250 ml of boiling tap water. 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 the 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 the gap width of 1.0 nm, using an inert gas (argon).

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.

Estimation of health exposure and risk of consumers

The exposure of consumers of herbal weight loss products to cadmium was calculated by 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):

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

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) [13] using the following equation:

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

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 [13].

Results

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 (Tab. I). 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), which contained the following ingredients: field horsetail, dandelion, chamomile, common knotgrass (*Polygonum aviculare*) and birch leaves.

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

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

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 (Tab. II). The mean concentration of the metal was almost twice higher 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). Cadmium concentration did not exceed the maximum allowable concentration in any infusion [15].

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, dandelion, field horsetail, nettle and L-carnitine, yerba mate, fennel, peppermint, anise, cumin, bladder wrack (*Fucus vesiculosus*), mulberry, rowanberry (*Sorbus aucuparia*), Pu-erh tea, green tea, rosehip (*Rosa canina*), *Garcinia cambogia* extract and wild pansy (*Viola tricolor*).

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

Samples	N	Concentration range (min-max)	Mean concentration ± Standard deviation	Maximum allowable concentration
				1.0*
Dietary supplements	17	< LOQ – 0.045	0.030 ± 0.012	
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 [15]				

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 the manufacturers no. III, VI, VII and XI were the most exposed to cadmium. The lowest intake of cadmium was found in consumers of products of the manufacturer no. XXVI (Tab. III).

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

	Exposure scenario						
	N	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

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

Estimation of the health risk did not show the 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. The higher the daily intake of infusions, the higher exposure to cadmium was. 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 (Tab. IV).

The highest health risk was estimated in the case of consumers of the infusion (3a) from the product of the manufacturer no III. In the case of consumption of three servings of infusion, the HQ was 0.48 for these individuals. The HQ higher than 0.4 was also found for consumers of the products of the following 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) (Tab. IV).

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

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

Discussion

The study found a higher contamination 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 has not been classified yet as foods intended for particular nutritional uses or dietary supplements.

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 or not they were classified as dietary supplements.

The products whose main ingredient was hibiscus were the most common among herbal remedies with the highest cadmium concentrations. 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, 19]. 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 bladder wrack 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 tea known as yerba mate. Barerlla et al. reported that one of the highest concentrations of heavy metals were found in dietary weight loss supplements containing yerba mate [20]. 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 [21, 22, 23]. The latter plant is a brown alga which occurs, e.g., in the Baltic Sea.

Since algae, including bladder wrack, have a high capacity to accumulate heavy metals [24], 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 three-fold higher value of maximum allowable concentrations of cadmium in the products 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 factor determining this process. It has been shown that the acidification of the solution significantly increases the migration of metals from the dried mass to the infusion, e.g., as a result of adding citric acid to tea infusions [25]. 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 [26].

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 of consumers, increased with the increase in the consumption of herbal products. None of the herbal remedies under study provided the body with such a high dose of cadmium that could be associated with 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

[27]. This problem is particularly important in the cadmium-contaminated areas due to the 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 to cadmium, thus posing a significant health hazard [28, 29]. 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 of 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 ensuring 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.

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. The total health risk of consumers resulting from the dietary exposure to cadmium could be high since the analyzed herbal products are not the essential part of the diet. 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.

Declarations

Competing interest: No

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- SupplementaryMaterialI.docx