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Evaluation of Metal and Microbial Contamination in Botanical Supplements

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The sale of botanical dietary supplements in the United States is on the rise. However, limited studies have been conducted on the safety of these supplements. There are reports on the presence of undesired metals in some of the botanical dietary supplements. In this study, echinacea, garlic, ginkgo, ginseng, grape seed extract, kava kava, saw palmetto, and St. John's wort supplements manufactured by Nature's Way, Meijer, GNC, Nutrilite, Solaray, Sundown and Natrol, have been analyzed for lead, mercury, cadmium, arsenic, uranium, chromium, vanadium, copper, zinc, molybdenum, palladium, tin, antimony, thallium, and tungsten using inductively coupled plasma mass spectrometry. All samples were devoid of mercury contamination. Results indicated that the botanical supplements analyzed did not contain unacceptable concentrations of these metals. These supplements were also evaluated for microbial contamination, and most samples analyzed showed the presence of bacteria or fungi or both. Microbes were not counted nor were microbial counts determined in these samples.

KEYWORDS: Echinacea; garlic; ginkgo biloba; ginseng; grape seed extract; kava kava; saw palmetto; St. john's wort; ICP-MS; metals; bacteria; fungi

INTRODUCTION

The market for botanical dietary supplements in the United States has increased over the past years (*1*). Some consumers depend on botanical dietary supplements to maintain mental acuity and to overcome problems associated with aging such as benign prostatic hypertrophy, elevated blood pressure and cholesterol levels, and the effects of menopause. Others resort to dietary supplements for energy and endurance and to relieve stress. Other reasons for the popularity of dietary supplements are higher health care costs and the desire for healthy living. However, very little is known about the safety of these supplements.

The Dietary Supplement Health and Education Act (DSHEA) of 1994 defines dietary supplement as "a product (other than tobacco) intended to supplement the diet that bears or contains one or more of the following dietary ingredients: vitamins; minerals; herbs or other botanicals; amino acids; dietary substances for use by man to supplement the diet by increasing the total dietary intake; or concentrates, metabolites, constituents, extracts, or combinations of these ingredients" (*2*, *3*). The safety of the dietary supplement is dependent on the growing conditions of the raw material and its extraction, formulation, and manufacturing processes. The pesticides used in the cultivation of botanicals might contaminate the dietary supplements as well (*4*). Earlier studies indicated the occurrence of relatively high concentrations of metals in botanical dietary supplements (*4*−*12*).

Inductively coupled plasma−mass spectrometry (ICP-MS) is one of the fastest growing techniques for trace element analyses because it enables rapid multielement determinations at the ultratrace level. Although other techniques such as flame atomic absorption (FAA), graphite furnace atomic absorption (GFAA), and inductively coupled plasma−optical emission spectrometry (ICP-OES) are efficient to determine low levels of elements, ICP-MS is superior mainly due to multielement capabilities, speed of analysis, low detection limits, and isotopic capabilities. This technique has been successfully used in the analysis of plant samples (*12*, *13*−*19*).

Echinacea, garlic, ginkgo, ginseng, grape seed extract, kava kava, saw palmetto, and St. John's wort are a few of the botanicals among the top 20 selling herbals in 1999 (*20*). We have analyzed these popular botanical dietary supplements for the presence of metals using ICP-MS. The metals quantified included lead, cadmium, arsenic, uranium, chromium, vanadium, copper, zinc, molybdenum, palladium, tin, antimony, thallium, and tungsten.

Microbial contamination is a concern associated with food products. Improper handling and storage of dietary supplements can result in microbial contamination. Therefore, we have also analyzed these supplements for microbial contamination.

MATERIALS AND METHODS

Inductively Coupled Plasma−Mass Spectrometry. The samples were analyzed using an inductively coupled plasma−mass spectrometer

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(Micromass Platform ICP-MS) using a Meinhard concentric nebulizer as the sample introduction system. The ICP-MS spectra were scanned for a period of 1.5 min. Before data acquisition, the ICP-MS was optimized with a standard solution that contained 10 μg/L of Be, Co, In, Ce, Bi, and U. Parameters such as torch position and gas flow rates were adjusted until the maximum and most stable signal was observed for a wide range of masses.

The concentrations were calculated on the basis of linear regression techniques using a series of standard solutions spiked with 40 ppm of calcium. The elements indium and bismuth were used as the internal standards. Standards that were within 15% of the expected concentrations were used to determine the calibration lines. The concentrations of standards ranged from 0.05 to 100 μg/L for ^{51}V, ^{52}Cr, ^{75}As, ^{98}Mo, ^{105}Pd, ^{114}Cd, ^{120}Sn, ^{121}Sb, ^{184}W, ^{205}Tl, ^{208}Pb, and ^{238}U and from 0.5 to 1000 μg/L for ^{63}Cu and ^{66}Zn, to ensure that unknown samples were within the range of the standards.

A Barnstead Thermolyne Corp. Nanopure Infinity Ultrapure water purification system (model D8961) was used for the preparation of the reagents. Standard solutions for calibration and internal standard solutions were prepared from commercial single-element analyte standard solutions (Spex, Fisher Scientific). Optima nitric acid (A467-1, Fisher Scientific) was used for the preparation of calibration solutions and for sample digestion. Reagent grade hydrochloric acid (A508SK-212, Fisher Scientific) was used for cleaning the Teflon vials and storage bottles.

Botanical dietary supplements, echinacea, garlic, ginkgo biloba, ginseng, grape seed extract, kava kava, saw palmetto and St. John's wort, sold under brand names such as Nature's Way, Meijer, GNC, Nutrilite, Sundown, Solaray, and Natrol, were procured in 2002 and 2003 from stores in Michigan, Illinois, and Indiana (**Table 1**). The bottles of dietary supplements were checked for the intactness of the seal, and they were stored in our laboratory shelves until analyses. The samples were analyzed within 3 months after the purchase.

Sample preparation and metal analyses were conducted in class 100 clean rooms. Teflon vials (0103L, Savillex) used for digestion of samples and Nalgene HDPE sample bottles (03-313-2A, Fisher Scientific) used for the storage of digested sample were rinsed three times with deionized water. They were then filled with hydrochloric acid solution (15%) and capped. The vials and bottles were then placed in a water bath (45 °C). After 24 h, the hydrochloric acid was emptied and the vials and bottles were rinsed with deionized water. They were then put in a tub containing deionized water. After 24 h, they were removed and dried under a class 100 HEPA-filtered laminar airflow hood.

Sample Digestion. The supplements analyzed were in the form of capsules, tablets, or soft gels. For capsules, the shells were removed and contents emptied into an agate mortar and ground well. Tablets were also made into a fine powder using an agate mortar and pestle. The soft gel capsules were weighed and digested, and each soft gel was considered as one analytical portion. The powdered samples were weighed (~400 mg) in acid-washed Teflon vials and capped. Ten milliliters of Optima nitric acid were added to the vials, sonicated for 2 h, and then left at room temperature for 4 h. The vials were then placed on the hotplate (~75 °C) for 16 h. Once the solutions were clear, 6 mL of Optima nitric acid was added to each vial and placed on the hotplate (~75 °C) for 24 h. The vials were then sonicated for 2 h, 6 mL of Optima nitric acid was added, and the vials were placed on the hot plate (~75 °C) for 18 h. The solution from the vials was evaporated, 10 mL of 10 M Optima nitric acid was added to the vials, and the resulting solution was stored at room temperature in 30 mL Nalgene HDPE sample bottles until analyses (*21*).

Quantification of Metals. Preliminary analyses of solutions prepared from supplements were carried out to determine the range of elements present in them beyond the background threshold. The results from the preliminary analysis indicated that lead, cadmium, arsenic, uranium, chromium, vanadium, copper, zinc, molybdenum, palladium, tin, antimony, thallium, and tungsten were present in detectable concentrations. We therefore chose to quantify these metals in the dietary supplements studied.

Preliminary analyses indicated that most supplements contained a high concentration of calcium and, hence, to match the matrix present in the samples, 40 mg/L of calcium was added to all of the calibration standard solutions. The solution analyzed in the ICP-MS had 1 mL of sample solution, 1 mL of 2% Optima nitric acid, and 2 mL of a solution of 20 μg/L of In and Bi, used as internal standards. The total daily intake of each metal, represented as micrograms per day, was calculated on the basis of the serving size and the number of recommended servings each day of a particular supplement (**Tables 3−10**).

Table 1. Botanical Supplements with Manufacturer's Batch Number and Expiration Date

botanical	manufacturer	batch no. (expiration date, MM/YY)
echinacea	Nature's Way	235204 (07/05)
	Meijer	2NB0648 (08/05)
	GNC	C49483 (10/04), 35181C4142 (09/05)
	Nutrilite	23101LLA (10/04)
	Sundown	497015 (08/04), 610683 (10/05)
	Solaray	062805 (11/05)
	Natrol	945598 (10/03)
garlic	Meijer	2HB1011 (11/03)
	GNC	2293GC0366 (07/05), 3803JC0366 (10/05), 32671C0366 (09/05)
	Nutrilite	2267YC7A (03/04)
	Sundown	793963 (07/04)
	Solaray	062609 (03/06)
ginkgo	Nature's Way	236066 (08/05)
	Meijer	2DB0857 (04/05)
	GNC	96199 (08/04), 0660BC4556 (02/05)
	Nutrilite	22680BUA (03/05)
	Sundown	357162 (05/04), 1518 (07/05), 357164 (05/04)
	Solaray	060909 (03/06)
ginseng	Nature's Way	235145 (07/04)
	Meijer	2FB0275 (05/05)
	GNC	2041FC4363 (09/08), 35061C4363 (06/06), 96293 (08/05)
	Nutrilite	2302U4LB (10/04)
	Sundown	809944 (07/04), 354550 (11/04)
	Solaray	062708 (02/06)
	Natrol	947806 (07/04)
grape seed	Nature's Way	226989 (06/05)
	GNC	0115AC4626 (08/05), C62819 (09/05), C64621 (01/05)
	Sundown	355357 (07/04), 355473 (06/04)
	Solaray	062604 (10/05)
kava kava	GNC	92297 (01/05)
	Sundown	158052 (05/05)
	Solaray	063008 (02/06)
	Natrol	944283 (10/03)
saw palmetto	Nature's way	245899 (08/05)
	Meijer	1DB0411 (09/05)
	GNC	2605GC4552 (07/06), 96065 (07/05), 95047 (06/05)
	Nutrilite	2263WSMB (08/05)
	Sundown	867899 (12/03), 867896 (07/05), 372498 (09/05)
	Solaray	060208 (02/06)
St. John's wort	Nature's Way	247066 (12/05)
	Meijer	1HB1220 (06/04)
	GNC	82151 (09/03), 96523 (09/05), 98387 (12/05)
	Nutrilite	1305POVA (10/03)
	Sundown	355700 (10/05), 354110 (01/04), 355701 (10/05)
	Solaray	062307 (01/06)
	Natrol	947225 (05/04)

Determination of Microbial Contamination. The bottles containing the dietary supplements were wiped with 70% ethanol under aseptic conditions in a laminar flow hood. This was to prevent any potential microbial contamination resulting from the storage of bottles in our laboratory. The bottles were opened under sterile conditions, and 1 unit of the sample was transferred into a test tube containing 5 mL of

Table 2. Minimum Risk Levels/No-Observed-Adverse-Effect Levels of the Elements per Day

metal	MRL/NOAEL/RDA	ref
mercury	50 μg for adults	*12*
lead	75 μg for adults, 25 μg for pregnant women, 6 μg for children	*26*
cadmium	14 μg[a]	*27*
arsenic	21 μg[a]	*28*
uranium	140 μg[a]	*29*
chromium	3 μg for males, 25 μg for females[b]	*30*
vanadium	210 μg[a]	*31*
copper	10 mg[c]	*32*
zinc	21 mg[a]	*33*
molybdenum	63 mg[c]	*34*
tin	21 mg[a]	*35*

[a] MRL. [b] RDA. [c] NOAEL.

Table 3. Concentrations of Metals Determined in Echinacea Supplements by ICP-MS[a]

metal	Nature's Way	Meijer	GNC	Nutri-lite	Sun-down	Sola-ray	Natrol
mercury	nd[b]	nd	nd	nd	nd	nd	nd
lead	0.567	0.440	0.927	0.093	0.710	2.901	0.034
cadmium	0.071	0.077	0.096	0.029	0.049	0.967	0.004
arsenic	0.434	0.137	0.793	0.150	0.235	0.908	0.027
uranium	0.133	0.024	0.744	0.095	0.064	0.173	0.002
chromium	8.838	2.033	9.374	4.340	4.516	4.562	0.125
vanadium	3.292	1.020	6.769	0.751	7.047	7.025	0.022
copper	34.715	17.389	10.428	12.684	14.404	33.353	1.302
zinc	38.761	22.013	31.284	8.861	24.830	79.683	3.202
molybdenum	2.757	0.894	1.514	0.541	0.690	3.154	0.184
tin	0.037	0.002	0.091	0.023	0.008	0.025	0.008
palladium	0.232	0.570	1.480	0.219	0.587	0.542	0.008
antimony	0.034	0.022	0.029	0.023	0.013	nd	nd
thallium	0.382	0.028	0.039	0.053	0.040	0.211	0.002
tungsten	1.723	0.343	0.836	0.353	0.165	0.263	0.027

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

physiological saline solution (1 unit of sample refers to 1 capsule/1 tablet/1 soft gel). The mixture was vortexed and then kept in the laminar flow hood for 30 min. The solutions/suspensions were then vortexed again and aliquots of 100 μL lawned on YMG plates (yeast, malt extract, and dextrose media) and incubated for 3−14 days at 28 °C. The plates were monitored for the growth of bacteria or fungi.

RESULTS AND DISCUSSION

The concentrations of metals present in the supplements studied were compared with the minimum risk level (MRL), the no-observed-adverse-effect level (NOAEL), or the recommended dietary allowance (RDA) for each element. The MRL and the NOAEL values are defined by the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services (*22*). MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure. MRLs are based largely on toxicological studies in animals and on reports of human occupational exposure. The given MRL is based on an average body mass of 70 kg. The NOAEL is defined as the dose of a chemical at which there are no statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control.

Table 4. Concentrations of Metals Determined in Garlic Supplements by ICP-MS[a]

metal	Meijer	GNC	Nutrilite	Solaray
mercury	nd[b]	nd	nd	nd
lead	nd	0.031	0.021	0.140
cadmium	0.137	0.030	0.012	0.068
arsenic	0.107	0.127	0.001	0.058
uranium	0.049	0.059	0.019	0.009
chromium	0.678	0.283	0.085	0.504
vanadium	0.126	0.081	0.025	0.196
copper	9.318	1.433	2.920	6.407
zinc	33.107	5.419	12.446	33.683
molybdenum	1.606	0.243	0.326	0.490
tin	0.005	0.005	0.016	0.012
palladium	0.070	0.089	0.019	0.097
antimony	0.005	0.025	0.002	nd
thallium	0.010	0.004	0.003	0.009
tungsten	0.256	0.056	0.047	nd

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

Table 5. Concentrations of Metals Determined in Ginkgo Supplements by ICP-MS[a]

metal	Nature's Way	Meijer	GNC	Nutrilite	Sun-down	Solaray
mercury	nd[b]	nd	nd	nd	nd	nd
lead	12.545	0.269	0.127	0.078	7.367	0.019
cadmium	2.886	0.042	0.030	0.020	0.041	0.011
arsenic	3.080	0.127	0.560	0.175	0.813	0.146
uranium	0.308	0.073	1.461	0.018	0.129	nd
chromium	12.876	5.705	0.181	0.358	6.113	0.051
vanadium	15.667	1.763	1.204	0.116	3.408	0.130
copper	24.135	5.058	0.533	0.529	7.218	1.694
zinc	98.493	11.137	140.999	3.461	11.558	10.117
molybdenum	0.659	1.249	0.225	0.098	0.476	0.991
tin	0.010	0.008	0.019	0.046	0.014	0.003
palladium	1.262	0.279	0.468	0.064	0.422	nd
antimony	0.061	0.050	0.017	0.006	0.052	nd
thallium	0.315	0.012	0.013	0.031	0.088	nd
tungsten	0.726	5.328	0.160	0.038	8.804	0.108

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

Effects may be produced at this dose, but they are not considered to be adverse (*22*). The RDA is listed for the metal when MRL/NOAEL values are not defined. The RDA is the average daily dietary intake level that is sufficient to meet the nutritional requirements of nearly all healthy individuals in a particular life stage and gender group (*23*). The MRLs/NOAELs/RDA of the metals analyzed in the supplements are listed in **Table 2**.

Concentrations (micrograms per day) of lead, cadmium, arsenic, uranium, chromium, vanadium, copper, zinc, molybdenum, palladium, tin, antimony, thallium, and tungsten quantified using ICP-MS in the supplements studied are listed in **Tables 3−10**. The results were compared with MRLs/NOAELs for each metal, and it was found that all supplements studied contained less than the minimum risk levels of the above metals for adults. The MRLs for palladium, antimony, thallium, and tungsten are not available.

Because of the widespread use of lead in plumbing and painting materials, its intoxication is a concern to both children

Table 6. Concentrations of Metals Determined in Ginseng Supplements by ICP-MS[a]

metal	Nature's Way	Meijer	GNC	Nutri-lite	Sun-down	Solaray	Natrol
mercury	nd[b]	nd	nd	nd	nd	nd	nd
lead	0.128	9.226	1.213	0.379	0.135	1.686	0.439
cadmium	0.121	0.177	0.076	0.025	0.021	0.158	0.020
arsenic	0.696	0.598	0.363	0.128	0.217	0.193	0.059
uranium	0.649	0.073	0.149	0.030	0.136	0.022	0.008
chromium	5.641	3.723	4.102	0.732	2.483	0.897	1.010
vanadium	3.774	2.429	0.606	0.178	0.895	0.650	0.148
copper	7.342	10.986	3.873	2.722	4.032	4.289	0.012
zinc	18.372	27.655	9.410	11.598	9.471	21.362	0.046
molybdenum	1.401	1.066	0.652	0.786	0.370	0.450	0.087
tin	0.050	0.035	0.110	0.034	0.077	0.012	0.017
palladium	0.318	1.147	0.477	0.132	0.064	0.706	0.213
antimony	0.111	0.039	0.063	0.009	0.014	0.021	0.010
thallium	0.059	0.026	0.013	0.013	0.011	0.013	nd
tungsten	0.473	1.052	1.800	0.261	0.259	0.839	1.593

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

Table 7. Concentrations of Metals Determined in Grape Seed Supplements by ICP-MS[a]

metal	Nature's Way	GNC	Sundown	Solaray
mercury	nd[b]	nd	nd	nd
lead	0.55	0.202	0.819	0.084
cadmium	0.020	0.051	0.017	0.007
arsenic	0.071	0.514	0.349	0.046
uranium	0.020	0.357	0.080	0.007
chromium	0.114	1.412	1.631	0.425
vanadium	4.398	0.647	1.299	1.830
copper	6.515	1.816	12.181	3.741
zinc	13.508	2.519	9.342	4.022
molybdenum	0.691	0.705	0.199	0.010
tin	0.031	0.087	0.111	0.097
palladium	0.010	0.312	0.070	0.091
antimony	0.318	0.122	0.029	0.133
thallium	0.001	0.015	0.011	0.002
tungsten	1.289	0.222	1.221	0.597

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

Table 8. Concentrations of Metals Determined in Kava Kava Supplements by ICP-MS[a]

metal	GNC	Sundown	Solaray	Natrol
mercury	nd[b]	nd	nd	nd
lead	0.576	2.346	0.331	0.245
cadmium	0.131	0.273	0.006	0.016
arsenic	0.113	0.341	0.034	0.091
uranium	0.068	0.035	0.026	0.068
chromium	5.409	3.292	0.603	0.692
vanadium	0.670	2.318	0.173	0.300
copper	7.402	13.371	1.067	1.487
zinc	23.797	42.887	2.411	2.861
molybdenum	0.545	0.188	0.030	0.132
tin	0.102	0.030	0.014	0.003
palladium	0.345	0.406	0.045	0.046
antimony	0.007	0.009	nd	nd
thallium	0.030	0.052	0.057	0.047
tungsten	0.671	0.467	0.038	0.052

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

Table 9. Concentrations of Metals Determined in Saw Palmetto Supplements by ICP-MS[a]

metal	Nature's Way	Meijer	GNC	Nutrilite	Sun-down	Solaray
mercury	nd[b]	nd	nd	nd	nd	nd
lead	0.009	0.129	0.371	0.036	0.050	0.782
cadmium	nd	nd	0.053	0.008	0.024	0.086
arsenic	nd	nd	0.034	0.250	nd	0.139
uranium	0.009	0.024	0.023	0.014	nd	0.009
chromium	0.169	0.375	1.612	0.228	0.169	0.700
vanadium	0.193	0.291	0.243	0.216	0.066	0.196
copper	0.156	0.382	27.891	10.976	20.280	sat[c]
zinc	0.619	0.299	47.971	8.549	23.788	sat
molybdenum	0.008	0.039	0.272	0.129	0.169	0.247
tin	0.007	0.003	0.078	0.021	0.009	0.077
palladium	nd	0.037	0.059	0.034	0.026	0.278
antimony	nd	nd	0.022	nd	nd	nd
thallium	nd	0.001	0.009	nd	nd	0.037
tungsten	0.068	0.029	8.767	0.466	5.181	2.040

[a] The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable. [c] Saturated the detector.

and adults. The human brain is most affected by lead doses. Children appear to be especially sensitive to lead because of a greater accessibility to lead in the nervous system of the young. Lead exposure has been correlated to decreased IQ and poor learning in children (*24*).

Our results indicate that the lead concentration in supplements analyzed did not pose a health risk to consumers, including pregnant women and children, because the tolerable intake levels for lead for adult and pregnant women are 75 and 25 μg/day, respectively. We also analyzed the supplements for uniformity between batches under the same brand names. One batch of echinacea by Sundown had 7.37 μg of lead, whereas the samples from the other two batches of the same product gave 0.24 and 0.30 μg of lead, respectively. This result indicated that batches of a product of the same brand might have botanicals sourced or grown under different environments.

The concentrations of cadmium, arsenic, uranium, chromium, vanadium, copper, zinc, molybdenum, and tin were found to be less than the respective MRL/NOAEL/RDA values in all of the botanical supplements studied. There were no reference data available in the literature for palladium, antimony, thallium, and tungsten, but their concentrations were low in most supplements. However, tungsten was present in ginkgo (Meijer), saw palmetto (GNC), and St. John's wort (GNC) at 5.33, 8.77, and 36.01 μg, respectively.

Zinc, copper, and molybdenum are considered to be good for human health. Zinc acts as a catalyst, coactive, or structural unit for some enzymes. Cuproenzymes, in which copper acts as cofactor, are essential for the normal functioning of the body. Molybdenum is a component of the sulfite oxidase enzyme. This molybdoenzyme catalyzes the last step in the pathway of degradation of sulfur amino acids (*25*). Zinc, copper, and molybdenum were present in high concentrations in all supplements analyzed.

Assessment of the Botanical Supplements for the Presence of Microorganisms. "Microorganisms" means yeasts, molds,

Table 10. Concentrations of Metals Determined in St. John's Wort Supplements by ICP-MS[a]

metal	Nature's Way	Meijer	GNC	Nutri-lite	Sun-down	Sola-ray	Natrol
mercury	nd[b]	nd	nd	nd	nd	nd	nd
lead	1.175	0.206	5.831	0.068	0.588	0.351	0.146
cadmium	0.054	0.080	2.115	0.047	0.092	1.114	0.156
arsenic	0.131	0.080	0.320	0.078	0.565	0.145	0.828
uranium	0.014	0.053	0.089	0.009	0.392	0.014	1.345
chromium	0.769	0.969	4.725	0.219	6.047	0.340	3.926
vanadium	0.373	0.354	3.487	0.063	2.935	0.248	3.513
copper	20.090	14.903	34.648	19.788	14.150	9.534	22.462
zinc	36.513	16.831	75.810	32.919	32.826	24.851	26.087
molybdenum	0.318	0.355	1.123	0.279	0.693	5.443	3.035
tin	0.031	0.018	0.132	0.017	0.305	0.013	0.637
palladium	0.061	0.055	0.594	0.106	0.242	0.078	0.578
antimony	0.014	0.025	0.044	0.003	0.013	0.005	0.060
thallium	0.017	0.005	0.030	0.003	nd	0.010	0.033
tungsten	0.107	0.524	36.006	0.094	0.314	8.933	0.476

*The values expressed in μg/day are calculated by taking into consideration the serving size of each supplement and the recommended number of servings each day. Serving size and recommended number of servings vary greatly for each supplement. Therefore, the values are given in μg/day and refer to μg/daily dose. [b] Not detectable.

bacteria, and viruses and includes, but is not limited to, species having public health significance. The term "undesirable microorganisms" includes those microorganisms that are of public health significance, which may subject a dietary product to accelerated decomposition.

Positive results were obtained for the presence of bacteria and fungi in most of the products tested. Microbial contamination in botanical supplements may result from production conditions and could decompose the supplement during storage. Microbial contamination can also occur due to improper handling of the material during production and packaging. Botanical supplements tainted with microorganisms could pose serious health risks to consumers. Therefore, further research is to be directed toward the identification of the type of microorganisms present in the dietary supplements. Typing the organisms can be helpful in distinguishing the microorganisms that will be of public health significance from the ones that are not harmful to human health.

Good Manufacturing Practices (GMPs) should prevent the presence of all microorganisms including undesirable microorganisms. Sourcing of the raw materials is also of great importance in improving the safety of the supplements. In conclusion, manufacturers of botanical supplements should emphasize and adhere to safety standards applicable to food processing in addition to efficacy and dosage.

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