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Organochlorine Pesticides and Metals in Select Botanical Dietary Supplements

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Fruits, vegetables and other food items are routinely monitored for pesticide and metal levels to ensure human health; however, many products which are used on a daily basis are not adequately monitored. Botanical dietary supplements, such as Ginseng, Valarian, etc, fall into this category. The use of botanical dietary supplements is increasing every year with some of the most recent figures indicating that 37 % of Americans are using these products (Brevoort 1999). Many of these products have been used for centuries in Europe and China, with reported instances of adverse human effects linked to metals (i.e. mercury, cadmium, lead, etc.) (Kew et al. 1993, Kabelitz 1998). The Food and Drug Administration (FDA) regulates dietary supplements under the Dietary Supplement Health and Education Act, which allows companies to make structure/function claims (Thomas 1996). However, few standards are present to insure the purity of these supplements.

The purpose of this study was to investigate the data gap associated with organochlorine pesticide and metal concentrations in the botanical dietary supplements Valarian, St. Johns's Wort, Passion Flower and Echinacea. In addition, a preliminary human health risk assessment was performed following United States Environmental Protection Agency (USEPA) Superfund guidelines.

MATERIALS AND METHODS

Valarian, St. Johns's Wort, Passion Flower and Echinacea (n = 5 to12 for each supplement) samples were purchased commercially from the United States. Samples consisted of solid formulations.

Metals (chromium, nickel, arsenic, cadmium, and lead) analysis was performed by weighing 3.0 g of each sample into a Teflon lined microwave digestion vessel (CEM Corp., Matthews, N.C.). To each vessel, 3 mL concentrated trace metal grade nitric acid, 2 mL concentrated trace metal grade hydrochloric acid, 2 mL concentrated trace metal grade sulfuric acid, and 5 mL Nanopure filtered deionized water were added. Vessel were sealed microwave digested (CEM Corp,

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model MDS-2100) for 40 minutes at 120 ^{0}C, and 130 Psi. Samples were transferred to volumetric flasks and a final volume of 100 mL was achieved with the addition of deionized water. Graphite furnace and flame atomic absorption spectrophotometery were utilized for analysis of chromium, nickel, arsenic and cadmium. The detection limits for water were 0.1 mg/L for Cr, 0.5 mg/L for Ni, 0.1 mg/L for Pb, 0.5 mg/L for As, and 0.2 mg/L for Cd. The detection limits for solid samples was 0.5 ng/g for Cr,1.0 ng/g for Ni, 0.5 ng/g for Pb,1.0 ng/g for As, 0.5 ng/g for Cd.

For organochlorine analysis, 5 g of sample was weighed glass centrifuge tubes and spiked with internal standards PCBs 103 and 198. Twenty milliliters of a 65% acetonitrile/water solution was added and samples were subsequently sonicated with a micro-probe fitted, 650 watt sonicator. Sample were centrifuged (IEC clinical centrifuge, setting 4), at room temperature, for 5 minutes and decanted into 125 mL borosilicate glass bottles containing 70 mL pentane washed deionized water, saturated with 2% sodium sulfate. Pesticide grade pentane (20 mL) was added to each bottle and shaken for a minimum of 2 minutes. The aqueous layer was allowed to separate from the solvent layer, at which point the solvent layer was removed using a glass pipette and transferred to an Erlenmeyer flask containing 15 grams of anhydrous sodium sulfate. Each sample was reduced to 10 mL in volume using a nitrogen evaporator (organomation N-EVAP) under heat (40-45 ^{0}C). Samples were run through a Florisil chromatography column (10 mm i.d. x 300 mm length, 5 g heated Florisil, 1.5 g sodium sulfate) to remove impurities. Columns were eluted with 25 % ethyl ether/pentane (v/v), 10% methylene chloride/pentane (v/v) and pentane. Sample volume was reduced to 20 mL using nitrogen evaporation, quantitatively transferred to 25 mL concentrator tubes, and further reduced to a final volume of 1 mL. Samples were transferred to auto-sampler vials and analyzed by a Hewlett-Packard 5890 series II gas chromatograph (GC) with data station. The GC was also equipped with dual injectors, dual electron capture detectors, auto-sampler, and J&W dual DB-5 columns (60m x 0.25mm x 0.25μ). Detection limits were 1 ng/g for all samples.

The daily adult exposure to metals and chlorinated pesticides in the sampled dietary supplements was quantified by utilizing an ingestion exposure model for contaminated fruits and vegetables. This exposure model, in conjunction with cancer slope factors (Sfs), reference doses (RfDs) and unit risk factors, was applied to estimate a carcinogenic and non-cancer related risk to human health (USEPA 1989, USEPA 1999). Daily intake of contaminants (mg/kg/day) was calculated utilizing the following equation:

$$\text{Intake} = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT},$$

where CF = contaminant concentration in the sample (mg/kg), IR = ingestion rate (kg/day), FI = fraction ingested (unitless), EF = exposure frequency (events/year), ED = exposure duration (years), BW = body weight (kg), AT = averaging time (days) where averaging time = ED x 365 days/year. Carcinogenic risk was quantified utilizing the equations:

$$Risk_i = Intake \times SF$$

$$Risk_T = \Sigma Risk_i$$

where $Risk_i$ = carcinogenic risk of individual contaminant, SF = slope factor, and $Risk_T$ = total risk of all contaminants. Quantification of chronic non-cancer hazard index was accomplished with the following equations:

$$\text{Hazard Quotient (HQ)} = \text{Intake} / \text{RfD}$$

$$\text{Hazard Index (HI)} = \Sigma \text{ Hazard Quotient}$$

where HQ = non-cancer risk of individual contaminant, RfD = reference dose, and HI = total non-carcinogenic risk of all contaminants.1000 mg/day was used as the ingestion rate (IR) for the samples. This value was based on the average calculated from the manufacturers recommended dosages (from product labels).

Table 1. Range of organochlorine pesticides and metals (ng/g) in four botanical dietary supplements.

	Valarian	St.John's Wart	Passion Fl.	Echinacea
Aresnic	1.6 - 8.5	6.5 - 17.8	2.4 - 12.4	2.1 - 10.2
Cadmium	57.2 - 959.7	56.3 - 851.0	263.7 - 966.7	37.7 - 898.6
Chromium	1.3 - 5.9	1.3 - 2.6	2.7 - 4.2	3.8 - 5.8
Lead	1.0 - 8.8	0.3 - 18.5	0.4 - 4.8	0.7 - 8.3
Nickel	1.7 - 25.0	2.0 - 7.3	2.7 - 8.6	3.0 - 8.2
Aldrin	ND[2] - 8.6	ND - 28.5	ND - 10.4	ND - 24.7
β-BHC	ND - 15.6	ND - 26.0	ND	ND - 26.7
γ-BHC	ND - 15.2	ND - 14.9	ND - 4.1	ND
Chlordane	ND - 9.3	ND - 10.9	ND	ND
α Chlordane	ND - 5.5	ND - 28.1	ND - 9.3	ND
O,P DDT	ND	ND - 19.3	ND - 31.2	ND
P,P DDT	ND - 12.9	ND - 7.0	ND - 8.9	ND
O,P DDE	ND - 5.1	ND - 9.6	ND - 4.1	ND
P,P DDE	ND - 4.9	ND - 8.5	ND - 3.6	ND - 3.4
O,P DDD	ND	ND - 4.7	ND	ND
P,P DDD	ND - 4.4	ND - 10.9	ND	ND - 17.1
Dieldrin	ND - 17.9	ND - 23.8	ND	ND - 1.2
Endrin	ND - 9.8	ND - 3.4	ND- 57.3	ND
HCB	ND	ND - 9.3	ND - 9.6	ND
Heptochlor	ND - 6.3	ND - 8.8	ND	ND
Heptachlor Ep.[1]	ND - 9.6	ND - 33.4	ND	ND
PCNB	ND - 16.6	ND - 22.0	ND - 12.0	ND - 6.3

[1] Heptachlor Epoxide

[2] No Detection

The exposure frequency (EF) used was 42 and 350 days/year to simulate both short-term and long-term usage. This rationale was developed from reports of individuals consuming dietary supplements on a regular or trial basis. A 30 year exposure duration was utilized for chronic non-cancer related risk, while a 70 year, lifetime exposure, was applied to carcinogenic risk calculations. Lastly, a default body weight (BW) of 70 kg and a fraction ingested (FI) of 100% were assumed for all analyses.

Human health risk due to lead exposure was determined by calculation of subsequent blood levels after ingestion of the herbal product. Blood lead levels were calculated utilizing California Department of Toxic Substances Control Lead Risk Assessment Software.

RESULTS AND DISCUSSION

Metals were detected in each of the samples (Table 1). Chromium, nickel, lead and arsenic were generally detected in concentrations $\leq$ 25 ng/g. However, cadmium was detected in much higher concentration ($\leq$967 ng/g) in all of the samples. St. John's Wort has been reported to be a cadmium assimilator and as such higher concentrations of cadmium in this plant should be expected (Kabelitz 1998). However, measured cadmium concentrations in this plant were not different than those observed in the other plants.

Metals are a common occurrence in the earth's crust and as such are present in the soil where these supplements are grown. So, it is expected that metals would be present in these supplements. In fact, plants are becoming increasingly popular in respect to remediation of metal contaminated sites. The uptake of the metals into the plant is based on several factors including soil pH, and redox. In addition, some plants have the ability to oxygenate there root zone thus impacting the bioavailability of the metal. So, there are several biological and physical factors that may influence the uptake of metals into these plants.

Organochlorine pesticides were also detected in each of the samples (Table 1). While most of the measured pesticides have been "banned" in the United States, they are commonly used in other countries. In addition, many of the pesticides bind strongly to sediments and soils thus increasing their persistence in the environment. Jacobs et al. (1998) detected organochlorine residues in dietary supplements containing fish oil, but levels were below the FDA limit for consumable food. Srivastava et al. (2000) noted that BHC and DDT were common contaminants in herbal preparations collected from India. Total DDT and BHC concentrations in the present study are similar to those measured by Srivastava et al. (2000), indicating that little intra-country variability exists in pesticide concentrations in these supplements.

Concentrations of metals and pesticides in these supplements resulted in a hazard

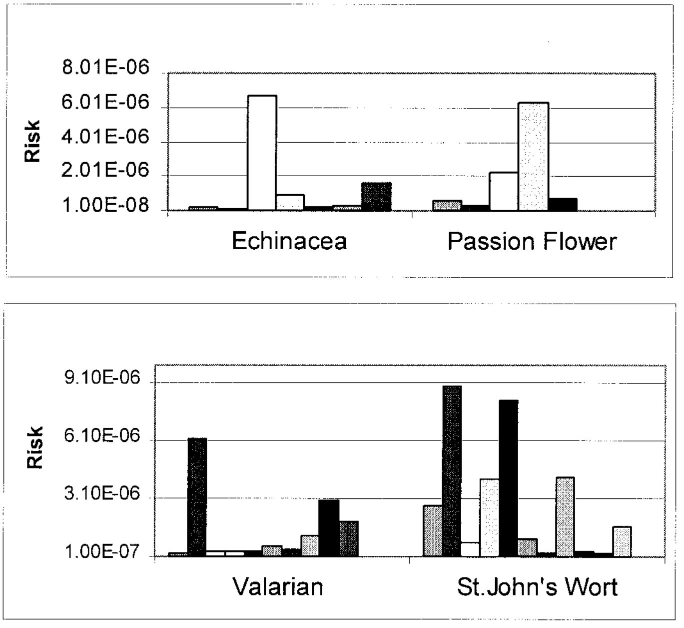

Figure1.Carcinogenic risk associated with ingestion of Echinacea, Passion Flower, Valarian and St. Johns Wort samples (350 d/yr at 1000mg).

index < 0.2, indicating that noncarcinogenic effects are unlikely (data not shown). However, concentrations in these botanical supplements did present a 1 X 10^{-6} risk in 40% of Passion Flower samples, 45 % of Valarian samples, 29 % of Echinacea samples and 58 % of St. John's Wort samples if 1000 mg were taken for 350 d (Figure 1). If the dose of the supplement was reduced to 100 mg/d or the exposure frequency was reduced from 350 d to 42 d, none of the samples exceeded 1 X 10^{-6} risk (data not shown). The observed risk in these samples were due exclusely to the organochlorine pesticides. No effects were predicted to occur based on the calculated blood lead levels. The calculated levels were similar to reported background concentrations (ASTDR 1996).

While the risk posed by these supplements is low, it should be noted that the number of samples analyzed for each of the botanical supplements is low ($\leq$12). A greater number of samples analyzed will allow for a greater risk prediction. In addition, additional metals and pesticides should be evaluated since some herbal products are grown in the United States (i.e selenium, methyl parathion, etc). This risk assessment in this study also used several assumptions. Assumptions such as exposure frequency and the amount of pesticide ingested should be further investigated. Many of the supplements investigated are in formulations that are quite different than those tested before, so absorption of contaminants from herbal supplements is a unanswered question. For instance, only 15 to 30 % of cadmium is absorbed from meats but, since herbal formulations are different a worst case scenario for absorption was utilized (i.e. 100% absorption) (ASTDR 1996). Assumptions used in this study need to be defined so that a more predictive risk model can be generated; however, this study does indicate that a potential human health concern exists.

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