A Comparison of Heavy Metals in Plant Based and Animal Meats and Fish by Microwave Digestion & ICP-OES and ICP-MS Analysis

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Introduction

Plant based meats are manufactured food items with the appearance, texture and taste of animal based meats. They are comprised of plant based protein and other ingredients to create a final product. Pea protein or isolate has become popular as it is a good source of iron and all nine essential amino acids. It was the protein ingredient of all plant based foods in our study. Other ingredients may be added to improve taste, texture, nutrition or color. These ingredients include metals such as Na, K ,Ca, Fe and Zn. Most plants are grown in soil which have some level of heavy metals that are natural in concentration. However some soil is contaminated with much higher concentrations via industrial pollution. Plants uptake metals in soils via the root and vascular system and stored in the leaves. Plants processed into vegan meat products will contribute to the metals concentration. Of particular concern are the heavy metals known as the big four (As, Pb, Cd, Hg) due to their acute toxicity. We will compare the metals results of plant vs animal based meats and fish samples using both ICP-OES and ICP-MS and discuss our findings.

Experimental

A total of eight samples were purchased at local grocery stores. We chose samples that were uncooked and minimally processed to reduce any contamination sources. Animal/Fish samples included ground beef, chicken and sausage as well as albacore tuna fish. The plant chicken and tuna samples were ground beef and sausage as well as chicken and tuna portions . Samples are shown in Figure 1.. Plant based chicken and tuna portions were ground using a SPEX Mini G 1600 with tungsten carbide milling balls. Two SRMs purchased from National Institute of Standards and Technology (NIST) were analyzed in this study to verify the sample preparation process. We used NIST1947 Lake Michigan Fish Tissue and NIST 1577C Bovine Liver.

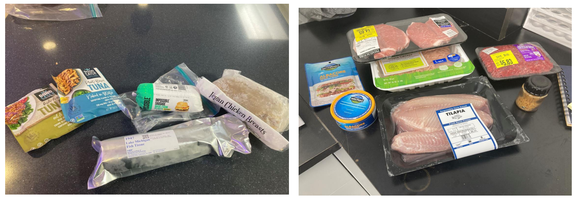

Figure 1. Samples analyzed in our study

All samples were digested using a CEM MARS6 with MARSXpress Plus Vessels (Figure 2). Samples were run in triplicate along with standards reference materials and QC check samples in a single batch run. The vessels incorporate a simple to assemble 3 part design.

Figure 2. MARS 6 with XpressPlus Vessels

Procedure and Method

All samples were weighed to 0.5 g dry weight equivalent, and placed into a MARSXpress Plus vessel. Eight mL of concentrated HNO_3 was added to each vessel and the samples were predigested for 15 minutes. Predigestion allows initial breakdown of the sample, particularly samples high in carbohydrates, After foaming and gassing subsided, 1 mL of 30% H_2O_2 was added to each vessel ann the samples were allowed to predigest for another 15 minutes. After the conclusion of the second predigestion the vessels were placed into the MARS 6. The EAM 4.7 digestion parameters are shown in Table 1.

Table 1. Digestion Conditions

MARS 6 Settings	EAM 4.7
Stage	1
Power	1800 W
Ramp Time	20:00 min
Hold Time	15:00 min
Temperature	200 C

At the conclusion of the second predigestion the vessels were placed into the MARS 6. The EAM 4.7 digestion parameters are shown in Table 1. Once the digestion process was complete the samples were cooled, opened and a 0.5 mL aliquot of HCL was added. The samples were then diluted to a final volume of 100 mL ready for analysis.

Based upon concentration elements were analyzed either by ICP-OES or ICP-MS. Calibration standards were matrix matched from 0 - 100 mg/L for ICP-OES and from 0 - 100 ug/L for ICP-MS for all elements. Na, K and Ca were analyzed using an Agilent 5100 ICP-OES while As, Pb, Cd, Hg, Se, Fe, and Zn were analyzed by an Agilent 7850 ICP-MS using the conditions in Table 2.

Table 2. Instrument Conditions

ICP-OES

Parameter	Value
RF Power	1200 W
Viewing Mode	SVDV
Viewing Height	8 mm
Nebulizer Flow	0.7 L/min
Plasma Flow	12 L/min
Aux Flow	1 L/min

ICP-MS

Parameter	Value for [He] mode
RF Power	1550 W
Sampling Depth	8 mm
Carrier Gas	1.05 L/min
Dilution Gas	N/A
Helium Cell Gas	5.0 mL/min
Energy Discrimination	5.0 V

Results

To verify the digestion process of the samples, two SRMs were analyzed by ICP-MS and ICP-OES. The results shown in Table 3 were in good agreement with the certified concentrations, where provided. All metals results are shown in Table 3. We then compared the oral daily limits set by USP 232/233 and ICH Q3D In general the plant based meat products were sli higher as compared to the animal meat and fish products for the Big 4 but are well below the limits set by the USP. This increase was likely due to the uptake from the soil. The plant based tuna was the exception as arsenic and mercury are much lower in the plant based sample. Sodium, potassium, and calcium are also elevated in plant based products which is likely from both the plant uptake from the soil in addition to the fact that salts are used as a seasoning to provide taste and texture. Zinc and iron are typically added to the plant based products for nutrition purposes. The iron in plant protein is not as abundant as in animal meat and zinc is added to animal feed and therefore is often used as a supplement in plant based foods. The iron results are very similar plant and animal foods. The zinc is typically higher in the plant based samples but less than half of the recommended allowance of 10 mg/day as established by the FDA for vitamins and supplements.

Results

Table 3. Quantitative results for samples

	As (ppb)	Cd (ppb)	Hg (ppb)	Pb (ppb)	Se (ppb)	Fe (ppm)	Zn (ppm)	Na (ppm)	K (ppm)	Ca (ppm)
Beef	2.634	0.2173	1.037	4.874	104.39	24.75	43.23	518.17	3399	46.29
Plant Based Beef	13.24	9.739	0.9196	5.911	73.62	31.5	41.61	3781	2692	223.9
Ground Chicken	0.5576	0.0776	0.848	2.449	157.8	5.682	14.39	529.5	2848	64.63
Plant Chicken Cutlet	4.329	14.61	0.9736	15.2	18.59	19.61	5.34	10096	789.1	420.04
Pork Sausage	0.5356	0.1246	0.6223	5.943	141.5	3.545	11.71	425.6	3182	39.14
Plant Sausage	9.059	18.12	1.833	17.6	54.9	19.01	37.63	7076	3957	1469
Tuna	1624.02	10.23	245.1	2.838	519.64	3.93	3.183	2060	2285	44.39
Plant Based Tuna	4.642	22.6	0.3313	3.575	72.62	32.67	13.78	3887	1206	434.5
1577C Bovine Liver	111.63	92.98	104.37	88.53	108.97	91.37	91.07	96.37	104.99	105.98
1947 Lake Michigan Fish Tissue	105.02	N/A	96	N/A	94.81	98.5	106.04	N/A	N/A	N/A

Each sample was digested and analyzed in triplicate. SRM recoveries are between 88 and 111% of reference values. All measurements of a single element are within 20% of each other further indicating that both the sample preparation and measurement are reliable and repeatable.

Conclusion

Plant based meats, fish and seafood are a rapidly expanding segment in the market place making it important for consumers to be aware of the heavy metals content. We found that the big four elements were higher in the plant based samples but at levels well below the oral daily limits set by USP 232/233 & ICH Q3D.. The plant based tuna had much lower concentrations of both mercury and arsenic as compared to tuna fish. The other elements we analyzed were usually higher in the plant based but well below recommended daily allowances. Future work will include adding more seafood and cooked products as well as looking at plant based dairy products.