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ELEMENTAL COMPOSITION AND POTENTIAL HEALTH IMPACTS OF *Phaseolus vulgaris* L. ASH AND ITS FILTRATE USED FOR COOKING IN NORTHERN UGANDA

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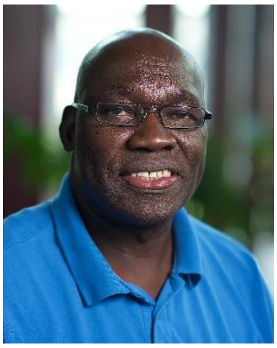

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ABSTRACT

Ash from burnt crop residue of common bean (*Phaseolus vulgaris* L.) is typically used to generate filtrate in rural Northern Uganda. The filtrate is added to hard-to-cook foods, like dried legumes, to decrease cooking time and improve flavor. However, the elemental composition of ash filtrate and health implications of its use is poorly understood. This study aimed to determine the elemental composition of *Phaseolus vulgaris* L. ash and its filtrate, to identify variation among study sites, and to assess the potential health impact of ash filtrate consumption in Northern Uganda. Dried ash and ash filtrate samples of *P. vulgaris* from Dog Abam, Telela, Arok, and Tit villages in Northern Uganda were analyzed for chemical composition. Ash filtrate samples were procured from ash according to local methods. Nutritional impact was assessed by comparing recommended daily intake (RDI) guidelines for Canada and Uganda. Potassium (K), sodium (Na), magnesium (Mg), manganese (Mn), and iron (Fe) concentration in dry crop ash samples varied significantly among study sites. Ash filtrate contained lower concentrations of all elements, suggesting considerable losses through filtration; but showed an alkaline pH (10.1 to 10.8). Elemental concentration present in probable daily intake of ash filtrate (approximately 15 milliliters/person) was within acceptable RDI ranges for elements of known dietary importance. The alkaline pH levels of the ash filtrate may have potential negative effect on diet by decreasing bioavailability of specific minerals (for example, Fe and Zn) and/or having destructive effects on various nutrients (for example thiamine). Further research should be conducted in Northern Uganda and other areas where ash filtrate is in use to determine the specific health effects of this cultural practice. Such studies could include, but not limited to, biological analysis, detailed nutritional studies, and/or long-term monitoring of filtrate consumers. The information gathered from such studies could be critical in formulating appropriate policies regarding the use of ash filtrate.

Key words: Food composition, nutrients, *Phaseolus vulgaris* L. ash filtrate, potential health problem, Uganda ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 16 No. 4 November 2016 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

INTRODUCTION

Plant parts have been used as a traditional type of salt additive in many parts of Africa [1- 5], Papua New Guinea [6, 7], and the United States [8, 9, 10]. In several regions in Africa, ash of common bean (*Phaseolus vulgaris* L.) is either eaten alone as a nutritional supplement or used in food preparation. However, high lead (11±2 mg/kg) and strontium (1870±190 mg/kg) in ash were observed to be of health concern because they exceeded the regulated tolerance levels in foods [9]. More recent analysis of essential elements present in *P. vulgaris* ash in Africa has shown varying levels of several minerals; for example, in Zambia, iron was reported at 41±3 mg/kg, copper at 4 mg/kg, and potassium at 650±109 mg/kg [3]. In Tanzania, *P. vulgaris* ash contained 1050±0.51 mg/kg iron, copper at 24±1.13 mg/kg, and potassium present at 646,600±82,500 mg/kg [5].

In Northern Uganda, ash obtained from burnt crop residue and dried plants is used to produce filtrate for cooking purposes. Local women state that when ash filtrate is added to the cooking water of hard-to-cook foods like dried legumes, it accelerates cooking time and adds a culturally preferred flavor to the dish [11]. The validity of these anecdotal claims was tested in an associated study [12]. The main concern regarding ash and ash filtrate use is that the filtrate can contain high levels of elements, such as iron, lead, and strontium that may be harmful to human health through the filtrate's consumption [8, 9, 10]. Burning crop residues vaporizes volatile or biological compounds [13], but concentrates elements in the form of ash [6]. Further, the plants are usually burnt with attached soil that may contribute additional elements to the ash mixture. Ferralsols, the dominant soils in this region, are acidic with high contents of iron and aluminum [14, 15, 16], and as such their enrichment may be of particular concern in the crop residue ash and filtrate.

To date, there has been no available data on the total elemental composition of common plant ash used in Uganda for traditional food preparation. There is no elemental analysis of plant ash filtrate, or investigation into the contributions of dry ash or filtrate to the daily mineral intake levels in the diet. Further, it has been presumed that bean crop ash contains high levels of sodium given its use as a traditional salt replacement; however, previous studies have been inconclusive [3, 5]. This study provides a comparative analysis of elemental composition of crop ash filtrate, dry crop ash and typical salt (ground salt and commercial salt) used in traditional food preparation in Northern Uganda, and explores the potential dietary nutritional impact of the daily use of ash filtrate.

MATERIALS AND METHODS

Study design and sample collection

Extensive time was spent in four communities observing and recording the range of activities associated with the traditional practice, including: harvest and curing of crops, legume harvest, burning of spent plant parts, collection and storage of ash, and procurement of ash filtrate.

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Four 150 g plant ash samples of the common varieties of *P. vulgaris* were collected from each of: Dog Abam, Arok and Tit (Oyam District) and Telela (Lira District), study areas in Northern Uganda. The samples were collected from two households at each study site, and generated from the 2011 and 2012 harvest years (n = 4x2x2 = 16). Lack of census data about households and access issues prevented a completely randomized sample collection. However, the samples are considered representative because crop harvest and ash burning are community activities. The ash is shared among several families within villages, precluding the need to analyze the variation within a village or community. Dried ash was collected using a plastic scoop. Two 500 g bags of ground salt (evaporites from a saline lake) from Lake Magadi (Kenya) were purchased in Lira, Northern Uganda. A 200 g sub-sample of salt was drawn from each bag. A 500 g bag of Chiluma iodized commercial sea salt (Kensalt Limited in Kenya) was purchased in Kampala and a 200 g sample was taken. All samples were stored dry and without preservative in 250 ml wide mouth high-density polyethylene (HDPE) containers, and labeled for transport to Canada. Sub-samples (n = 16) of dry ash and salts (approximately 5 grams each) were used to determine the elemental contents at the University of Northern British Columbia (UNBC).

Ash filtrate preparation

Ash filtrates were prepared at UNBC as similar as possible to the method employed by the local women in the study areas in Northern Uganda. Ash samples from the same household at each study site were combined to meet the 250 g necessary to generate ash filtrate from each study site, except from Telela where four samples were combined (n = 1) due to limited quantity of ash (total n=7). The 250 g of loose, dry ash was placed into an unbleached coffee filter to mimic the rudimentary spear grass filter typically used in the study areas. The filter with ash was placed into a perforated (0.5 cm holes at the bottom) plastic cup from Uganda. The cup was washed and rinsed with Type 1 water[1], and dried prior to use and in-between samples to prevent any cross contamination. A small portion of 200 ml of Type 1 water was added to the ash to form a filter bed. The remainder of the water was slowly added and percolated through the ash and collected in another plastic cup as ash filtrate. Filtrate samples were stored without preservatives in sterile 20ml glass scintillation vials prior to the determination of elemental contents. The pH of each filtrate sample was taken using an electronic Bluelab® pH pen.

Bean sample preparation

Sample collection taken from 240 g dried beans subjected to various treatments was completed after each cooking trial. The treatments were (in 2.0 L cooking water): Control - distilled water; Table Salt - 5.7 g of commercial iodized salt (0.23% w/v); Ground Salt - 5.7 g of ground salt (0.23% w/v); and Ash Filtrate - 45 ml of plant ash filtrate (1.8% v/v) from the Dog Abam study site. Wet samples (approximately 10 g) of drained cooked beans were collected in sterile 20 ml glass scintillation vials from each pot after beans were cooked to a 150 g puncture force. Moisture content of air-dried beans was determined by oven-drying at 60°C for 24 hours.

[1] Ultrapure water filtered with a Millipore® system meeting ASTM® standards for Type 1 water

Total elemental analysis
Crop ash, salt and bean samples (approximately 0.4 g each) were oven-dried at 70-80°C overnight (48 hours for bean samples), and digested in a microwave oven by using 4 ml concentrated nitric acid following Environmental Protection Agency (EPA) Method 3052 [17]. The digested samples were heated to 230°C for ten minutes and diluted to 50 ml with Type 1 water. Aqueous filtrate samples (9 ml) were acidified with 1 ml of nitric acid, heated on a 10 minute ramp to 180°C, held at 180°C, and then diluted to 50 ml with Type 1 water (following EPA 3015A method) [18]. Samples were analyzed with inductively coupled plasma mass spectrometry (ICP-MS) (Agilent 7500Cx) for a full spectrum of elemental constituents.

Nutritional analysis
A subset of elemental contents was further investigated based on nutritional guidelines for Canada and Uganda [19, 20]. Macro elements were identified as dietary minerals needed in amounts over 100 mg/day and micro elements identified as those required in much lower quantities [21]. Additional elements were included in the analysis because they are potentially required, of unknown necessity, or have been suggested as potentially harmful elements [22, 23].

Sample calculations
The daily elemental intake from filtrate was calculated as follows:

*Daily elemental intake from filtrate (mg) = elemental concentration in filtrate (ng/ml) * 15 ml * 1 mg / 1000000 ng* (1)

where a daily intake of 15 ml represents the typical amount of filtrate used to cook the commonly eaten dried legumes in the study areas.

Daily intake of elements from bean consumption was calculated using the following relationship:

*Daily intake of element from dried beans (mg) = elemental concentration in oven-dried bean values (mg/kg) * 0.077 kg oven-dried bean* (2)

where 0.077 kg is equivalent to an 80 g portion of air-dried beans typically consumed on a daily basis in the study areas. A moisture content of 3.9% was used in the calculations based on results of moisture content analysis of beans used in the study.

To determine the proportion of an element extracted from the ash, the following equations were used:

*Proportion (%) = (total elemental amount in 200 ml filtrate (mg) / total elemental amount in 250 g ash (mg))*100* (3)

where total elemental amount in 250 g ash is the quantity of ash used to produce filtrate (that is, elemental concentration in oven-dried weight (mg/kg) * 0.25 kg = mg of element) and total elemental amount in 200 ml filtrate is the volume of Type 1 water used to produce filtrate (that is, elemental concentration in filtrate (mg/l) * 0.2 l = mg of element). Average elemental values for dry ash (n = 16) and filtrate (n = 7) for each study site were used for the calculations. The proportion of extracted elements shows the percentage of transferred elements from oven-dried ash to filtrate through the filtrate procurement process.

Statistical analyses

Two assumptions were made prior to the statistical analysis of the elemental contents of the samples. First, that harvest year of ash generation was not an independent variable because ash is used up to and past the harvest year. Secondly, ash does not differ between households because neighbors often share ash burning duties and, therefore, the produced ash. Households included in this study were not randomly chosen for this reason and due to lack of census data and time constraints. Analysis of variance was used to identify differences among study sites; statistical analysis was completed with Stata® (Version 12), and significant differences were determined by a p-value < 0.05.

RESULTS

Elemental content of dried ash

The elemental content of oven-dried crop residue ash samples varied among sites (Table 1). In general, elemental concentration at the Arok site was lower than other sites while ash samples from the Dog Abam site showed generally higher concentrations of elements. Manganese contents statistically varied the most among sites (326 mg/kg - 963 mg/kg, $p < 0.05$), but potassium had the greatest range in values (165,577 mg/kg at Dog Abam to 88,188 mg/kg at Arok).

Elemental content of ash filtrates

The amount of elements extracted from the ash and leached into the ash filtrate filtration was generally quite low. Highest proportions extracted were of molybdenum (6 - 35%), silicon (9 - 19%), sodium (6 - 9%), potassium (5 - 7%), and rubidium (5 - 7%). The filtrate sample from Dog Abam used for subsequent estimation of elemental consumption testing showed higher concentration for most elements (for example, calcium, phosphorus, iron, and manganese) and was lower only in magnesium (Table 2). However, it appears that there is very little elemental concentration in a typical daily consumption of approximately 15 ml of filtrate (Tables 2 and 3). Filtrate pH levels varied between sites; 10.1 at the Telela site, 10.3±0.4 at the Tit site, 10.5±0.1 at the Arok site, and 10.8±0.1 at the Dog Abam site, demonstrating the filtrate is of a highly alkaline nature.

Elemental content of legumes prepared with ash filtrates

Elemental contents of beans cooked in each treatment were used to calculate the associated concentrations present in daily serving amounts (80 g), which are displayed against recommended daily intake (RDI) tables for adults (Table 4). Differences among treatments are generally not pronounced, with the exception of high sodium levels in the table salt and ground salt treatments. Boron, aluminum, and strontium were the only elements which exceeded set upper limits of RDI. However, contents of several other elements including nickel, rubidium, barium, and titanium could not be assessed based on lack of sufficient data for regulations.

DISCUSSION

Concentration of calcium, magnesium, potassium, iron, manganese, boron, strontium, barium and aluminum in ash residues are fairly high, and consistent with earlier findings [3, 5, 8, 10]. Iron and aluminum are particularly abundant in the soils of the region [15], and are easily taken up by plants in acidic soil conditions such as those in Northern Uganda [24, 25]. As such, the elevated content of these elements in the ash was to be expected. There is likely a further addition of elements into the ash from the inadvertent inclusion of soil attached to the plant parts during harvest, and when ash is scooped from the ground after the plant parts are burnt. Elemental transfer from ash to ash filtrate is generally in very low amounts except for molybdenum and silicon. Subsequently, elemental concentration in the amount typically consumed per person per day (Table 2) is very low. Variations in elemental levels among both dry ash and ash filtrate samples may be the result of using different varieties of *P. vulgaris*, different maturity of the bean samples, annual growth patterns, or simply due to inherent variation within samples.

Legumes (beans) make up a significant percentage of the diet in Northern Uganda and are eaten on a daily or almost daily basis. A typical daily serving size is approximately 80 g dried (240 g cooked) beans cooked with 15 ml filtrate per person, eaten over two to three meals throughout the day. Elemental contents in a 15 ml ash filtrate do not appear to be a health concern as they are well within the dietary reference intake amounts for required macro or micro elements by both Ugandan and Canadian standards [19, 20]. There are also no detectable levels of any potentially toxic metals (for example, mercury or lead) to pose a health risk (Table 4). As the diet in rural Northern Uganda is generally quite limited, it is possible that the filtrate is actually providing a small amount of supplemental elements to their diet. For example, a typical daily consumption of filtrate could provide minor contributions between 100 mg and 200 mg of potassium. Similar elemental concentrations of beans cooked in Type 1 water (Control) and those cooked with ash filtrate reflect the low mineral input from filtrate (Table 4). In a typical daily portion size for adults (240 g of cooked beans), there are no elemental levels in the ash filtrate treatment of any health concern (Table 4), and only the level of boron exceeds RDI or upper limit (UL) set by Ugandan or Canadian guidelines. However, the level of boron in all treatments was comparable (including those cooked in plain water), and is, therefore, an inherent property of the beans themselves and not an issue being introduced by the cooking additive.

Concern about the nutritional impact of using ash filtrate appears to rest predominantly with the alkaline pH level which could cause deleterious and counteractive nutritional effects [5]. The filtrate created from ash from Dog Abam has an alkaline pH of 10.8 ± 0.01, most likely due to the high content of potassium. Highly alkaline food additives can have various negative consequences on the nutritional aspects of cooked beans, including: a decrease in bioavailability of iron (37%) and zinc (35%) [14], a loss of nutrients, particularly thiamine [26, 27] and riboflavin [3], and destruction of essential amino acids [28].

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CONCLUSION

This study examined the the elemental composition of *Phaseolus vulgaris* L. ash and its filtrate, identified variation among study sites, and assessed the potential health impact of ash filtrate consumption in Northern Uganda. Based on the results of the study, it can be concluded that the use of ash filtrate has potential negative dietary consequences (decreased mineral bioavailability and/or nutrient destruction) due to its alkaline nature.

RECOMMENDATIONS

While this study provides a foundation platform to study the use of ash filtrate and other similar cooking practices in other regions, financial and logistical constraints prevented a more in-depth anlysis of health impacts of the practice. Furthermore, given the potentially detrimental nutritional aspects of consuming foods prepared with ash filtrate, it is recommended that further investigation of individuals in this area be conducted to accurately identify elemental levels present through hair, blood, sweat, and urine sampling, and to identify the bio-accumulation of any elements (for example, aluminum). Additionally, a more in-depth survey of current health status should be completed. These investigations could help to provide a conclusive stance on the nutritional effects of using ash filtrate in food preparation.

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Table 1: Mean contents of elements in ash samples from Dog Abam, Telela, Arok and Tit sites in Northern Uganda

Element		Crop Ash Residue							
		Dog Abam (*mg/kg*)		Telela (*mg/kg*)		Arok (*mg/kg*)		Tit (*mg/kg*)	
Calcium	Ca	77600	± 2290 [a]	101000	± 126 [a]	77100	± 13700 [a]	86900	± 1750 [a]
Phosphorus	P	13500	± 1200 [a]	12200	± 166 [a]	8940	± 1720 [a]	8070	± 635 [a]
Potassium	K	166000	± 5270 [a]	143000	± 1250 [ab]	88200	± 17100 [b]	160000	± 932 [ab]
Sodium	Na	435	± 73 [a]	221	± 3.32 [a]	148	± 5.33 [b]	168	± 3.71 [ab]
Magnesium	Mg	35500	± 1760 [a]	21500	± 185 [b]	19800	± 2650 [b]	29800	± 873 [ab]
Iron	Fe	3640	± 26.3 [a]	6190	± 166 [a]	7470	± 949 [ab]	10700	± 483 [b]
Zinc	Zn	180	± 19.5 [a]	143	± 1.62 [ab]	88.5	± 11.4 [ab]	83.6	± 2.35 [b]
Manganese	Mn	963	± 113 [a]	326	± 5.28 [b]	458	± 6.03 [c]	544	± 12.7 [ac]
Copper	Cu	52.0	± 4.03 [a]	95.0	± 1.79 [a]	78.9	± 17.0 [a]	48.2	± 2.24 [a]
Selenium	Se	1.12	± 0.04 [a]	0.838	± 0.03 [a]	0.972	± 0.10 [a]	1.21	± 0.03 [a]
Molybdenum	Mo	0.437	± 0.03 [a]	2.00	± 0.06 [a]	1.17	± 0.28 [a]	0.487	± 0.03 [a]
Chromium	Cr	14.4	± 0.18 [a]	8.90	± 0.20 [a]	23.6	± 3.68 [a]	16.2	± 2.27 [a]
Nickel	Ni	36.8	± 7.78 [a]	7.64	± 0.14 [a]	11.0	± 1.35 [a]	9.00	± 0.37 [a]
Cobalt	Co	19.4	± 4.25 [a]	3.23	± 0.09 [a]	4.18	± 0.70 [a]	4.03	± 0.12 [a]
Arsenic	As	0.383	± 0.01 [a]	0.40	± 0.01 [ab]	0.598	± 0.07 [ab]	0.700	± 0.03 [b]
Boron	B	274	± 2.15 [a]	246	± 2.40 [a]	170	± 26.1 [a]	278	± 9.81 [a]
Silicon	Si	437	± 13.2 [a]	256	± 5.15 [b]	244	± 9.32 [b]	245	± 6.08 [b]
Vanadium	V	13.9	± 0.36 [a]	13.3	± 0.34 [a]	20.2	± 2.66 [a]	23.8	± 0.95 [a]
Rubidium	Rb	138	± 17.3 [a]	91.4	± 0.76 [a]	122	± 28.4 [a]	94.5	± 5.72 [a]
Strontium	Sr	641	± 4.80 [a]	1060	± 12.9 [a]	747	± 148 [a]	620	± 15.7 [a]
Barium	Ba	1590	± 140 [a]	1070	± 11.6 [a]	805	± 104 [a]	770	± 63.6 [a]
Aluminum	Al	11200	± 81.2 [a]	13700	± 375 [a]	13610	± 1840 [a]	16600	± 757 [a]
Lead	Pb	3.28	± 0.15 [a]	2.39	± 0.05 [a]	4.99	± 0.96 [a]	3.78	± 0.39 [a]
Mercury	Hg	0.0105	± 0.0004 [a]	0.00800	± 0.0006 [a]	0.00646	± 0.0003 [a]	0.0211	± 0.002 [a]
Titanium	Ti	206	± 18.1 [ab]	291	± 8.12 [a]	112	± 8.10 [b]	286	± 9.26 [a]

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Ash samples (n=16) are mean values (± standard error). Values along rows with the same superscript are not significantly different ($p > 0.05$) by the Tukey's HSD method

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Table 2: Mean values of pH and select essential elemental concentrations of ash filtrate samples from Dog Abam, Telela, Arok and Tit sites in Northern Uganda

		Blank*		Crop Ash Filtrate						
				Dog Abam		**Telela**	**Arok**		**Tit**	
pH				10.8 ± 0.1		10.1	10.5 ± 0.1		10.3 ± 0.4	
Element										
Ca	*(mg/l)*	0.121	±0.0816	118	±34.2	60.7	65.1	±2.73	66.0	±4.86
	(mg/15 ml)	*na*		1.78	±0.512	0.911	0.977	±0.0410	0.990	±0.0729
P	*(mg/l)*	<0.005	±<0.001	29.8	±9.72	2.65	5.06	±0.672	3.28	±0.598
	(mg/15 ml)	*na*		0.448	±0.146	0.0398	0.0759	±0.0101	0.0492	±0.00897
K	*(mg/l)*	0.0256	±0.00201	13300	±2910	8840	7330	±3160	14300	±360
	(mg/15 ml)	*na*		199	±43.7	133	110	±47.4	215	±5.41
Na	*(mg/l)*	1.03	±0.00485	47.4	±2.75	16.8	11.7	±0.251	16.7	±3.36
	(mg/15 ml)	*na*		0.711	±0.0412	0.252	0.175	±0.00376	0.251	±0.0504
Mg	*(mg/l)*	0.00770	±<0.0001	12.2	±11.9	173	166	±41.8	125	±124
	(mg/15 ml)	*na*		0.183	±0.180	2.59	2.50	±0.627	1.88	±1.87
Fe	*(mg/l)*	0.000774	±<0.0001	0.41	±0.398	0.00502	0.0125	±0.000203	0.0102	±0.00714
	(mg/15 ml)	*na*		0.00612	±0.00597	<0.001	<0.001	±<0.001	<0.001	±<0.001
Zn	*(mg/l)*	0.000411	±<0.0001	0.055	±0.0521	0.00195	0.00247	±0.000264	0.00113	±0.000180
	(mg/15 ml)	*na*		0.000827	±0.000782	<0.001	<0.001	±<0.0001	<0.001	±<0.0001
Mo	*(mg/l)*	0.000313	±<0.0001	0.092	±0.0499	0.180	0.0891	±0.0543	0.210	±0.124
	(mg/15 ml)	*na*		0.00137	±0.000749	0.00270	0.00134	±0.000815	0.00316	±0.00186
B	*(mg/l)*	1.18	±0.0216	16.9	±3.86	4.04	2.56	±0.459	8.49	±1.02
	(mg/15 ml)	*na*		0.254	±0.0579	0.0606	0.0385	±0.00688	0.127	±0.0152
Si	*(mg/l)*	0.762	±0.0127	102	±36.5	29.8	26.5	±2.85	38.5	±8.77
	(mg/15 ml)	*na*		1.52	±0.548	0.446	0.398	±0.0428	0.577	±0.131

Ash filtrate samples (n=7; n=2 for each study site except for Telela where n=1) are mean values (± standard error). Elemental concentration in 15 ml of filtrate (typically consumed per person on a daily basis) is derived
na = not available
* The blank sample is an average of duplicate Type 1 water samples

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Table 3: Mean values of pH and select non-essential elemental concentrations of ash filtrate samples from Dog Abam, Telela, Arok and Tit sites in Northern Uganda

		Blank*		**Crop Ash Filtrate**						
				Dog Abam		**Telela**	**Arok**		**Tit**	
pH				10.8 ± 0.1		10.1	10.5 ± 0.1		10.3 ± 0.4	
Element										
Rb	(*mg/l*)	<0.0001	±<0.0001	10.7	±2.84	5.69	10100	±7720	5.61	±1.50
	(mg/15 ml)	*na*		0.161	±0.0425	0.0854	0.151	±0.116	0.0842	±0.0225
Sr	(*mg/l*)	<0.0001	±<0.0001	0.231	±0.130	0.261	0.263	±0.0701	0.0951	±0.0565
	(mg/15 ml)	*na*		0.00346	±0.00195	0.00392	0.00395	±0.00105	0.00143	±0.000847
Al	(*mg/l*)	0.00141	±<0.001	2.30	±2.26	0.0126	0.0224	±0.0155	0.0225	±0.00188
	(mg/15 ml)	*na*		0.0345	±0.0339	<0.001	<0.001	±<0.001	<0.001	±<0.001
Pb	(*mg/l*)	<0.0001	±<0.0001	0.0027	±0.00261	0.00035	0.00014	±<0.0001	0.00003	±<0.0001
	(mg/15 ml)	*na*		<0.001	±<0.0001	<0.0001	<0.001	±<0.001	<0.001	±<0.0001
Hg	(*mg/l*)	<0.0001	±<0.0001	0.00012	±<0.0001	0.00003	0.00004	±<0.0001	0.00004	±<0.0001
	(mg/15 ml)	*na*		<0.001	±<0.0001	<0.0001	<0.001	±<0.001	<0.001	±<0.001

Ash filtrate samples (n=7; n=2 for each study site except for Telela where n=1) are mean values (± standard error). Elemental concentration in 15ml of filtrate (typically consumed per person on a daily basis) is derived

na = not available

* The blank sample is an average of duplicate Type 1 water samples

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Table 4: Daily intake of elements (mg) from an 80 g serving size for adults of air-dried beans cooked in Plain (Control), Table Salt, Ground Salt and Ash Filtrate and recommended daily intake (RDI) and upper limit (UL) amounts for Uganda (National Drug Authority 2009) and Canada (Health Canada 2010)

Element		Uganda*		Canada*		Treatment			
						Control	Table Salt	Ground Salt	Ash Filtrate
		RDI	UL	RDI	UL	(*mg*)	(*mg*)	(*mg*)	(*mg*)
Macro	**Ca**	1000	2000	1000	2500	104	94.9	167	124
	P	1000	2000	1000	2500	332	392	344	327
	K	3500	7000	4700	nd	919	1090	1030	987
	Na	2400	4800	1500	2300	44.6	786	868	50.3
	Mg	400	800	320/420	350**	124	142	143	120
Micro	**Fe**	8/18	36	8/18	45	4.40	5.39	15.6	5.22
	Zn	15	30	8/11	40	2.38	2.43	1.97	2.40
	Mn	2	4	1.8/2.3	11	1.43	1.50	2.01	1.83
	Cu	2	4	0.90	10	0.832	0.743	0.721	0.816
	Se	0.070	0.14	0.055	0.40	<0.001	0.01	<0.001	<0.001
	Mo	0.075	0.15	0.045	2	0.148	0.114	0.134	0.136
	Cr	0.20	0.40	0.030	*nd*	0.0202	0.0293	0.0685	0.0228
	Ni	*nd*	*nd*	*nd*	1	0.178	0.170	0.155	0.132
	Co	*na*	*na*	*na*	*na*	0.0302	0.0308	0.0337	0.0222
Trace	**As**	*nd*	*nd*	*nd*	*nd*	<0.001	<0.001	0.00	<0.001
	B	*nd*	3	*nd*	20	7.21	6.52	6.44	7.66
	Si	*nd*	*nd*	*nd*	*nd*	35.1	36.2	43.7	36.9
	V	*nd*	*nd*	*nd*	*nd*	0.00	0.00	0.05	0.01
Unknown necessity or toxic	**Rb**	0	*na*	0	*na*	0.806	0.965	0.869	0.800
	Sr	0	0	0	0	0.753	0.589	1.65	0.848
	Ba	0	*na*	0	*na*	0.764	0.547	1.06	0.714
	Al	0	0	0	0	5.88	6.56	16.90	6.66
	Pb	0	0.243	0	0	0.0015	0.0019	0.0067	0.0020
	Hg	0	0	0	0	<0.001	<0.001	<0.001	<0.001
	Ti	*na*	*na*	*na*	*na*	0.0782	0.152	3.25	0.135

na = not available; *nd* = lack of sufficient data
*Recommended daily intake (RDI) and upper limit (UL) levels are for healthy, 19-50 year old individuals, differentiated for males/females if applicable
**The upper limit for magnesium is for intake from a pharmacological source only and does not apply to intake from food or water

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