Determination of Baseline Data on Heavy Metals in Yellow-Flesh Sweet Potato (*Ipomoea Batatas*) of Trinidad

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ABSTRACT

This study was aimed at determining the level of baseline data on heavy metals in yellow flesh sweet potato (*Ipomoea batatas*) from six selected agricultural farms in Trinidad and to indicate possible source of contamination risks. Samples of soil and sweet potato tuber, vines and leaves were collected in January 2018.Across all tissue samples of sweet potato, heavy metals were present in the concentration order Zn >Cu>Pb>Ni>Cd. The stem and leaves concentrate more heavy metals than edible tuberous roots. All metal BAF was less than one (BAF<1) and TF> 1 which shows sweet potato effectively translocate these metals from tuber to shoot. Essential micronutrients Zn, Cu and Ni were below WHO ML while the non-essential elements Pb and Cd exceeded the WHO ML limits.

Key words: sweet potato, contamination, bioaccumulation factor, translocation factor.

INTRODUCTION

Agricultural soils normally contain a low background level of heavy metals. The main anthropogenic sources of contamination in agriculture soils include: industrial fallouts and industrial emission, waste disposal, urban effluents, pesticides and fertilizer applications [1], [2]. and can increase the level of heavy metals in soil and create a health hazard to the people, plants and animals, but also threatens food quality and hence the food safety [3]. Applications of fertilizers and other soil amendments can add small amounts of heavy metals to the soil which can build up over time with repeated applications.

Heavy metal intake via soil-crop has been considered as the predominant pathway of human exposure to environmental heavy metals in agricultural areas [4]. The absorbance of heavy metal from the soil depends on different factors such as pH, organic matter, soil metal availability, CEC (Cation Exchange Capacity), plant species and the presence of other metals [5]. The health effects of exposure to heavy metals depend on the amount and duration of exposure, such as quantity of contaminated soil or food consumed over time.

Three heavy metals of greatest health concern among few others are Cd, Pb and Hg (Danuta Witkowska*, 2021). They have no known biological function. The increase in environmental pollution caused by toxic metal is of great concern due to their carcinogenic properties, their non – biodegradability and bioaccumulation [7]. It has been estimated that more than 70 % of dietary intake of Cd is contributed via food chain [8]. Prolonged consumption of contaminated foodstuff may lead to accumulation of toxic metals in the liver and kidney of humans resulting in disturbances of biochemical processes such as liver, kidney,

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cardiovascular, nervous and bone disorders [9], [10], [11]. Some metals such as Cu, Zn, Mn, Co and act as micronutrients for the growth of animals and human beings when present in trace quantities while others such as Cd, Pb, As and Cr act as carcinogens [12].

The contamination of agricultural produce due to soil contamination poses a threat to both the quality and safety of food. Dietary intakes of heavy metals also pose risks to animals and human health [13]. Tukdogen et.al (2002) discussed high concentrations of heavy metals (Cu, Cd and Pb) in fruits and vegetables were related to high prevalence of upper gastrointestinal cancer [14].

Sweet potato (*Ipomoea batatas*, Lam) is a root crop which supports millions of people throughout the tropical region of the world. The sweet potato originated in Central America, but at present it is widely grown in many tropical and subtropical countries in different ecological regions. It is the top three root and tuber crops produced and consumed in the Caribbean [15]; and is the seventh largest food crops grown in tropical, subtropical, and warm temperate regions of the world [16]. It is an important agronomic advantage of root crops as staple foods as it is adaptable to diverse soil and environmental conditions and a variety of farming systems with minimum agricultural input. The sweet potato is grown all around the year under suitable climate conditions and complete loss under adverse climate conditions is rare and thus considered as an insurance crop [17]. Sweet potato is considered as a typical food security crop for disadvantages population mostly in the third world countries as the crops can be harvested little by little over a long period of time.

Sweet potato is very popular in Trinidad and Tobago and is consumed in all households. Due to rising prices of imported food globally, there are opportunities of utilizing traditional root and tuber crops such as cassava and sweet potato. Consumers are encouraged to transition from imported grains and cereal to more traditional staples through local markets, not only for fresh but various forms of processed traditional staples at a minimal cost. Sweet potato is used in bread, pies, pone, and chips. Sweet potato fries are now available in fast food restaurants as a substitute for white potato fries. CARDI and Ministry of Food Production have made significant interventions to strengthen production and processing operations, over the past five years [15].

1.1 Nutritional Value

Sweet potato (*Ipomoea batatas*, Lam) is known to be one of the most important crops of the world because of not only its considerable amount of nutrients but also the phytochemicals content in its tuber root and leaves. Among other root and tuber crops, sweet potato contains a higher content of carbohydrates, various vitamins, and proteins than many other vegetables. According to USDA (2022), agriculture research service, sweet potato also contains a much higher level of provitamin A and vitamin C than wheat or rice [18].

Sweet potatoes are rich in dietary fiber, minerals, vitamins and antioxidants, such as phenolic acids, anthocyanins, tocopherol and beta carotene [19]. They are a good source of protein and Vitamin A, C and B2 (Riboflavin). The protein content of the sweet potato leaf is double that of the tuber root. In addition to its nutritional value, sweet potato is recognized as a functional food containing high levels of various phytochemicals having beneficial health effects [20]. Studies have indicated that phytochemicals such as polyphenols have high free- radical scavenging activity, which help to reduce chronic disease such as cardiovascular disease, cancer and age-related neuronal degeneration [19]. Most studies on phytochemicals in root and leaves of sweet potatoes indicate that their health promoting properties were related to the high levels of polyphenols, for example, Rabah et.al. (2004) demonstrated that sweet potato extract offered cancer prevention activity which was correlated with level of phenolic content [20]. The leaves are also an excellent source of lutein, which is responsible for central vision in the human eyes and helps protect eyes from oxidative stress and high energy photon of blue light [21].

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The aims of the study are (a) Determine the mobility of heavy metals in soil by assessing the uptake by sweet potato plants. (b) Compare results against WHO/FAO maximum tolerable level in sweet potato.

MATERIALS AND METHODS

Distilled and deionized water was used for sample preparations and cleaning of glassware. To avoid contamination all laboratory glassware utensils used were washed and rinsed in tap water before soaking overnight in 10 % Nitric acid, rinsed with deionized water, and placed in oven of 50^0C for drying. All reagents used were of Analytical Grade.

Sample Collection and Preparation

Sweet potato samples were collected from 6 randomly selected sweet potato farms in Trinidad and Tobago from small holder's agriculture farms (Fig.1). Five samples were collected from each field (n=30). Tuber roots were collected with the leaves from each selected spot and put in separate polythene bags and brought to the laboratory. Samples were cleaned and rinsed with distilled water. Tubers were peeled and split into smaller pieces. Both the tuber and leaves were dried in an oven at 70^{o}C for 48 hrs. The samples were ground with a blender to <2mm. Each ground sample was placed in a clean polythene bag, mixed well, labeled, and stored until needed for analysis.

Figure 1: Sampling locations (F1-F3, Farms 1-3, all Felicty; F4-Farm 4, Caparo; F5-Farm 5, Mamoral RD; F6-Farm 6, Central)

Extraction and Analysis

Determination of heavy metals in sweet potato

The method of determining heavy metals in sweet potato tissues was optimized for highest recovery using samples of tubers, stem, and leaves. For optimal extraction, triplicates 2.00 g aliquots of plant samples 10 mL concentrated HNO_3 was added and pre-digested at room temperature for 12hrs, followed by complete digestion on a heating block at 130^{o}C for 3hrs. Digested extracts were cooled, diluted with 5mls of deionized water, filtered through Whatman No.542 filters and made up to 25ml, for heavy metal

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determination by flame atomic absorption spectrometry (FAAS). There was no available reference plant material for heavy metal analysis. However, for the validation of HNO_3 total extractable metals methods, soil reference material was used, and the recovery percentage recorded.

Table 1: Mean concentration ± Std. deviation and % recovery NIST Certified Reference Materials – SRM 2709a

Extractable Methods	**Metals**	**Certified value**	**Mean value**	**% Recovery**
SRM – HNO_3		µg/g	µg/g	
	Cd	0.33-0.66	0.24±0.02	73
	Pb	8.1-11	8.12±0.18	100
	Zn	69-87	65.1±1.46	94
	Cu	24-28	57.9±7.08	95.8
	Ni	59-71	22.9±0.09	98

Bioaccumulation and translocation factor of heavy metals

Plant to soil relationships was assessed for heavy metal accumulations in shoots and roots. Heavy metal translocation factor from shoot to root was measured by TF which is given below.

$$TF = C_{shoot}/C_{root} \quad (1)$$

Where C_{shoot} and C_{root} are metal concentrations in the shoot(mg/kg) and root(mg/kg) of the plant respectively. TF> 1 represent that translocation of metal effectively was made to the shoot from the root (ref: Mohammad Rezvani1, Faezeh Zaefarian).

STATISTICAL ANALYSIS

The means of heavy metal determined were found to be statistically significant ($p < 0.05$) as determined by one way analysis of variance (ANOVA). Mean metal concentration in soil [22] showed no significant difference in heavy metal concentration in soil.

RESULTS AND DISCUSSION

Results from this research showed heavy metal concentrations in the leaves and stems of Yellow Flesh Sweet Potato compared to tubers.

Table 2: Heavy metal concentrations (mg/kg dry wt.) in agricultural soils from selected small-scale farms in Trinidad[22]

	Heavy metal concentration in soil mg/kg				
Location	Cd	Pb	Zn	Ni	Cu
F1	0.48	12.1	79.1	15.5	14.1
F2	0.35	10.6	78.1	19.7	12.9
F3	0.6	11.5	93.3	25.1	15.3
F4	0.59	12.9	44.4	9.74	12.7
F5	0.63	8.31	12.7	5.63	7.19
F6	0.33	6.26	9.74	5.07	8.45

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Table 3: Bioaccumulation and Translocation Factor of heavy metals in sweet potato

Loc.	**H/metal**	**Cd**	**Pb**	**Zn**	**Ni**	**Cu**
F1	Root	0.24	0.59	4.32	3.3	2.83
	Stem	0.49	0.89	15.4	4.51	20.5
	Leaves	0.32	0.71	22.1	6.53	9.49
F2	Root	0.24	0.24	7.52	1.31	1.80
	Stem	0.49	4.01	18.5	1.48	9.28
	Leaves	0.41	1.16	25.1	4.29	9.17
F3	Root	0.1	3.47	4.55	2.69	3.70
	Stem	0.29	6.54	19.2	1.06	10.3
	Leaves	0.15	6.02	26.7	2.19	13.0
F4	Root	0.07	6.60	11.2	1.43	3.56
	Stem	0.20	6.73	24.2	3.76	9.21
	Leaves	0.15	6.02	26.7	2.19	13.0
F5	Root	0.14	4.00	7.75	0.77	4.26
	Stem	0.19	5.99	25.2	1.78	8.23
	Leaves	0.15	7.18	20.4	3.32	11.7
F6	Root	0.15	0.52	7.99	0.71	4.32
	Stem	0.17	6.52	25.4	0.93	12.0
	Leaves	0.14	3.49	34.2	2.68	15.5
WHO/FAO max limit ML		0.1	0.3	100	67	73

Table 4: Bioaccumulation and Translocation Factor of heavy metals in sweet potato (r/s-root/soil, s/r-stem/root, l/r-leaves/root)

Loc.	**Elements**		**Cd**	**Pb**	**Zn**	**Ni**	**Cu**
F1	BAF	r/s	0.50	0.05	0.05	0.21	0.20
	TF	s/r	2.04	1.51	3.56	1.37	7.24
	TF	l/r	1.33	1.20	5.12	1.98	3.35
F2	BAF	r/s	0.69	0.05	0.10	0.07	0.14
	TF	s/r	2.04	16.7	2.46	1.13	5.16
	TF	l/r	1.70	4.83	3.34	3.27	5.09
F3	BAF	r/s	0.17	0.30	0.05	0.11	0.28
	TF	s/r	2.90	1.88	2.16	0.39	2.78
	TF	l/r	1.50	1.73	5.87	0.81	3.51
F4	BAF	r/s	0.12	0.51	0.25	0.15	0.28
	TF	s/r	2.86	1.02	2.16	2.63	2.59
	TF	l/r	2.14	1.04	2.13	4.84	2.44
F5	BAF	r/s	0.02	0.48	0.61	0.14	0.59
	TF	s/r	1.36	1.02	3.25	2.31	1.93
	TF	l/r	1.07	1.80	2.63	4.31	2.75

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F6	BAF	r/s	0.45	0.08	0.82	0.08	0.52
	TF	s/r	1.13	12.5	3.18	1.31	2.75
	TF	l/r	0.93	6.71	4.28	3.77	3.55

Table 5: The average concentration of heavy metals in the roots (tubers) and leaves (shoot) of yellow-flesh sweet potato *(Ipomoea batatas*). Summary of bioaccumulation and translocation factor.

	Conc.mg/kg		BAF	BAF	TF
Elements	roots	leaves	roots/soil	leaves /soil	leaves /roots
Cd	0.16	0.22	0.32	0.44	1.38
Pb	2.57	4.1	0.25	0.40	1.60
Zn	7.22	25.9	0.14	0.49	3.59
Ni	1.70	3.53	0.13	0.26	0.02
Cu	3.41	13.8	0.29	11.8	4.05

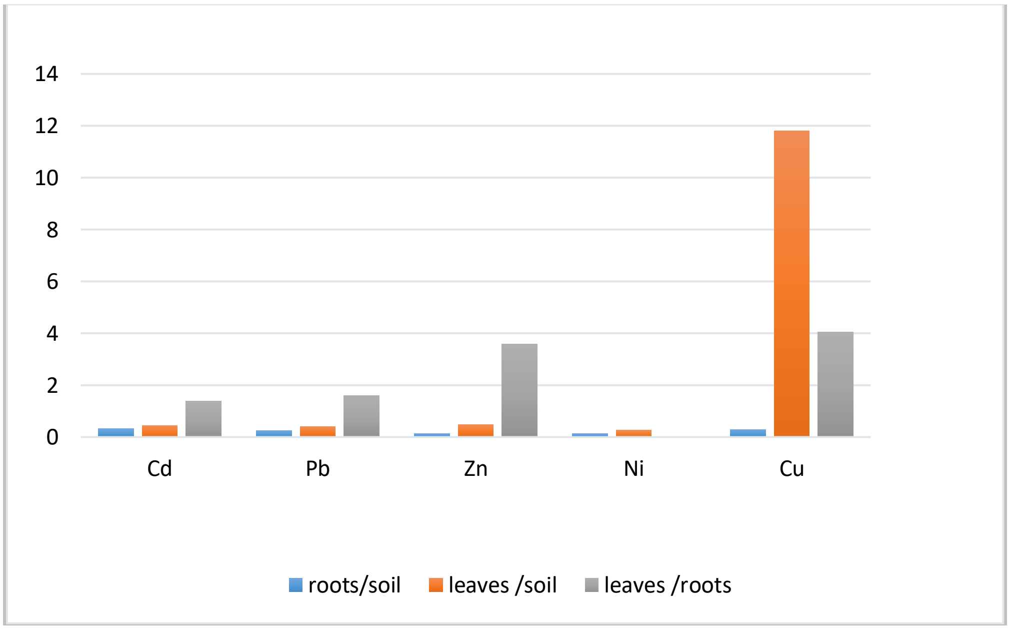

Figure 2 Bioaccumulation Factor (BAF) in roots and leaves and the Translocation Factor of *Ipomoea batatas*. The above graph shows a significant difference in distribution of Cu concentrate in sweet potatoes. Significant differences in heavy distributions show Cu>Zn>Pb>Cd>Ni. Sweet potato is safe for consumption due to high metal translocation factor.

Zinc Mean concentration was lower than the WHO M L and the TF values were between 2.13 -5.12. TF >1 means that translocation of Zn effectively from root to shoot. Zinc is an essential micronutrient in human diet as it is required to maintain proper functions of the immune system, the normal brain activity and is fundamental in the growth and development of the fetus [23]. Zn deficiency in the dietary may be detrimental to human health than excess Zn in the diet. Zn shortage causes birth defect and anemia, stomach cramps and vomiting and skin irritation [24] etc. The average daily intake of Zn is 7-16.3 mg Zn/day and the dietary allowable limits recommended for male is 15mg/day and 12mg/day for women [25] . TF > 1 for Zn suggests the preferential accumulations to the shoots than in the root.

Nickel concentrations in all studied tubers were below WHO ML (Table 2). This suggests that the tuber under study is free of Ni contamination and is safe for human consumption. Low BAF was observed for Ni.

Copper. High Cu concentrations were found in stem than in roots. Low BAF values were observed in the tubers suggests that none of the tubers were contaminated with Cu. Normal concentrate of Cu in plant tissue is approximately 5-25 mg/kg [26]. All Cu concentration was less than the WHO recommended value. High TF values (1.93-7.24) showed that transport of Cu from root to leaves was effective and hence the sweet potato is a potential Cu-accumulator.

Cadmium. Cadmium accumulated more in stems and leaves than in roots. Cd in tuberous roots was between 0.07 – 0.24 mg/kg. It is higher than the WHO maximum level of 0.1 mg/kg (table 2). The lowest concentration was observed in Farm 4 where there was presence of high Pb and Zn. Low BAF values of Cd were observed generally, however high TF (stem/root) values (1.13 –2.90 mg/kg) of Cd in sweet potato was observed. The lowest Cd observed in farm 4 has the highest TF than the others. A key trait of metal hyper accumulators is the efficient metal transport from roots to shoots, characterized by the TF being greater than one [25]. Based on the TF >1 observed in sweet potato means sweet potato are potential Cd – hyper accumulators.

Lead. Pb in Farm 4, 5, 3, 1, 6 exceed the WHO/FAO maximum limits in sweet potato. Lead is highly toxic and harmful to man. Low BAF values were also observed in Pb, but high TF values (0.71-31.1) showed that the transport of Pb from roots to leaves is very effective. Hence the sweet potato is a potential Pb-Hyper accumulator. The presence of Pb affects the gastrointestinal track, kidneys and central nervous system. Children exposed to Pb are at risks of mental deterioration, risk for impaired development, lower IQ while adult may experience loss of memory, nausea, insomnia, anorexia, and weakness of joints [25].

All heavy metals Cd, Pb, Cu, Ni and Zn accumulated more in stem and leaves of yellow flesh sweet potato (chicken foot) than in the root of the tuber (Table 2). Cd and Pb in sweet potato exceed the WHO maximum level of 0.3 mg/kg and 0.1mg/kg on dry weight basis and the Cu, Zn and Ni are below the maximum level [27]. From this result the yellow flesh sweet potato can be effectively used for biomonitoring of Cd, Pb, Cu, Ni and Zn. Although low BAF values were generally observed in all metals however, High TF were observed in the yellow flesh sweet potato in the following order of TF, Pb (9.25)> Zn (3.94)> Cu (3.39)> Cd (2.33)> Ni (1.79). Efficient metal transport from roots to shoots (stem & leaf) is a key trait of metals hyper accumulators, characterized by the TF being greater than one. Basing on the result, the TF>1 observed in yellow flesh sweet potato, means that the yellow flesh sweet potato is potential hyper accumulator of Pb, Zn, Cu, Cd and Ni hyper accumulator plant [25].

The concentration of Zinc in sweet potato (*Ipomoea batatas)* was higher than the other metals present. This can be explained by nearly 200 three-dimension structure of Zn protein representing, all six classes of enzymes (oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases [28] and functions as an enzyme activator in carbohydrates metabolism and protein formation. High level of Zn has also been detected in vascular tissues, which are mostly found in the skins of sweet potatoes [29].

High concentration of Zn in the sweet potato reduces concentration of Cd, because Zn being an essential micronutrient for plants and animals; its substitution by Cd may cause the malfunction of the metabolic processes [30]. The physical and chemical properties of soil such as Cd content, pH and competitive ions are responsible for accumulation of Cd in plants [30], [31].

CONCLUSION

The determination of heavy metals Cd, Pb, Zn, Cu and Ni concentrations in tissues of yellow flesh sweet potato showed the metal concentration in the following order: Zn >Cu>Pb>Ni>Cd. The stem and the leaves take up more heavy metal concentration than the tubers. Although the bioaccumulation factor BAF <1, the translocation factor, TF>1 indicates that sweet potato effectively translocated all metals from root to shoot (stem and leaves) effectively. This means that sweet potato can effectively be used for biomonitoring of Zn, Cu, Ni, Pb and Cd. The high amount Zn/Cu is adventurous for the removal of Cd. Higher concentrations of Zn and lowest concentration of Cd are evident in farm 4 as Zn and Cd compete in metal uptake. Lead was more effectively translocated from roots to shoots than the other metals. However, the concentrations of Pb and Cd exceed the WHO maximum limit 0.3 mg/kg and 0.1mg/kg respectively. It therefore is necessary to continue monitoring the heavy metal content in sweet potato to ensure that level is safe for human consumption. From this study consumers of sweet potato must warn of consuming sweet potato leaves as high metal concentration accumulates in shoots.

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