Arsenic Contamination of Selected Indigenous and Exotic Leafy Vegetables in the Eastern Cape Province of South Africa

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***Abstract*—The presence of some essential (iron, copper, chromium, selenium and zinc) and toxic (arsenic, cadmium, lead and mercury) metals in two cultivated *Brassicca* species (*oleracea* and *rapa*) and two indigenous leafy vegetables (*Chenopodium album* and *Solanum nigram*) were examined in samples collected from two areas of Mthatha region of the Eastern Cape Province of South Africa. The dried leaves of plants were prepared using standard laboratory procedures and analysed using atomic absorption spectrometry for elemental composition. Each element was calculated as percentage dry matter. The concentrations of potassium, calcium and magnesium, sodium and iron were found to be the most abundant components while copper, chromium, selenium , zinc and arsenic were the minor elements Cadmium, lead and mercury were not detected while traces (< 0.05mg/Kg) of antimony and tin were found in all samples. Currently there is a renewed interest in the consumption indigenous leafy vegetables which were popular among the rural population as a source of macro and micronutrients. Indigenous leafy vegetables also play very important nutritional roles in the food security of the rural population. The results of this study indicating the presence of arsenic in the leafy vegetables grown in the area is a cause for concern. Further studies are required to establish the source and extent of this contamination in other areas of the province, speciation of arsenic as arsenic and other toxic metals are reported in water, soils and vegetables grown in home gardens in mineral rich South Africa.**

***Index Terms*—arsenic, exotic, indigenous leafy vegetables, toxic metals, human health.**

I. Introduction

In South Africa, household food security in rural populations is challenged by unemployment, HIV/AIDS and poverty [1]. High rates of population growth result in ecosystem destruction that is associated with industrial and commercial development. This worsens the already food insecure situation and loss of dietary diversification. Greater importance has been placed on the production and consumption of cash crops such as maize, rice and wheat by the colonial economies, leading to the displacement of indigenous food crops. This caused changes in the complex and diverse food habits of the African people [2]. The consequences of nutrition transition from pulses, fruits and vegetables to simplified diets devoid of micronutrients and non-nutrient bioactive protective components pose enormous health and development challenges. Micronutrient deficiency continues to be a major health problem in developing countries and has far reaching consequences on growth, development, and health especially among children and other vulnerable groups. Communities that are economically and socially deprived in developing countries have dietary intakes that usually consist of plant-based staple foods which are monotonous and lack diversity [3]. Progressive neglect of a significant proportion of the diverse food available in our environment namely the indigenous leafy vegetables which were once popular in the rural households have disappeared from the food tables of the poor because of their low status as nutrient foods and stigma attached to it as old fashioned poor man’s food. Paucity of scientific data available on their nutritive value is responsible for this neglect. Focusing on a few staple foods or cheap cereals to address this situation and neglecting the indigenous and traditional food systems has further narrowed the food supply base and resulted in micronutrient deficiency, obesity and other non-communicable diseases. To revive livelihood options for the poor and malnourished in rural and urban communities, it is necessary to revitalize and draw on the existing indigenous and traditional knowledge on food systems by promoting the use of biodiversity [2]. South Africa is listed by the World Health Organization (WHO) as one of the 36 high-burden countries due to a malnutrition challenge that is of public health significance [3]. Food insecurity and malnutrition are highest in provinces with large rural populations such as KwaZulu-Natal, Northern Province, Eastern Cape, and the Free State [4]. South Africa is endowed with agro-biodiversity that consists of a wide variety of indigenous leafy vegetables collectively known by names like ‘imifino, morogo and muhuro in local regional languages ‘such as isi Xhosa, isi Pedi and Tsivenda respectively [5]. These groups of plants are neglected by the youth in the rural communities though they served substantially in the food security of the region in the past. The current

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neglect and under-utilization of these plants are mainly due to the lack of scientific knowledge and information about their nutrient composition and stigma attached to them as ‘poor mans’food choices. It is only appropriate to create an evidence based awareness that would encourage consumption and commercial production of these leafy vegetables in an attempt to curb the high level of under-nutrition and hidden hunger prevalent in rural communities and food insecurity in rural households. Recent reports published in literature suggests the use of some of these indigenous leafy vegetables for their medicinal properties.

Against the above background a comparative study was undertaken to examine the nutrient composition including the mineral composition of some exotic cultivated leafy vegetables (*Brassica rapa* (mustard spinach) and *Brassica oleracea* (Kale Chou Moelier) and some indigenous leafy vegetables (*Chenopodium album* (lambsquarter /Imbikicane) and *Solanum nigrum* (nightshade/Umsobo). that were popular choices with the older generations in rural South Africa. The exotic cultivated leafy vegetables like *Brassica rapa* and *Brassica oleracea* were included in the study for comparison. The paper only reports on the mineral compositions of the above leafy vegetables and the detection of arsenic in them.

II. Materials and Methods

Brassica rapa and *Brassica oleracea* were collected from a home garden, *Chenopodium album* and *Solanum nigrum* were collected from an open felt around households. All samples were collected in the morning to avoid uncontrolled environmental stress. The plants were randomly picked. The samples collected represented the stage of development that would normally be harvested for consumption, typically young shoots and leaves. The collected plant material was placed in polyethylene bags to prevent loss of moisture during transportation to the laboratory and processed on the same day that they were harvested. The leaves were thoroughly washed and rinsed with clean water, separately, to remove dirt and other contaminants. Taxonomical identification of the plants was done by Dr Immelman of the Kei Herbarium at Walter Sisulu University, Botany Department. Voucher specimens (CN01, CN02, CN03, and BG01) for *C. album*, *S. nigrum*, *B. oleracea* and *B. rapa*, respectively, were deposited in the Kei Herbarium for future reference. Leaves were dried, powdered , ashed and acid digested and used for elemental analysis using atomic absorption spectrophotometry. Concentration of each element in the sample was calculated on percentage (%) dry matter i.e. mg/100g sample [6].

III. Results

Major minerals of the leafy vegetables included calcium, potassium, magnesium, iron and sodium as shown in Table I. The major minerals found in the leafy vegetables both *Chenopodium album and Solanam nigram* compared well with the exotic leaves *B rappa and B olaracea.*.

TABLE I. Major Minerals of the Selected Vegetable (Mg/Kg) DW

Element	*C. Album*^{y}	*C. Album*^{m}	*B. oleracea*	*S. nigrum*	*B. rapa*
Ca	12991 ±717	18213 ±598	32288 ±613	16890.0 ±1488	18126 ±30
K	45799.3 ±12	49028 ±593	17813 ±376	61120.2 ±155	44959.0 ±1869
Mg	7982 ±175	13821 ±493	3820 ±63	14407.8 ±173	13628.2 ±12
Fe	218.1 ±2.6	120.4 ±4.1	177 ±8.1	90.8 ±6.8	128.0 ±5.7
Na	48.8 ±0.4	68 ±3.6	165 ±3.9	116.9 ±5.3	68.2 ±1.1

^{y}Young shoots , ^{m}Mature plant with flowers, DW dry weight
Data are means ±SD of duplicate determinations for each nutrient

The results indicated the presence of Ca, K, Mg, Fe and Na in good amounts. Particular mention is to be made about Ca and Fe as these minerals are obtained in lesser quantities in the poor rural diets. *Chenopodium album* is normally consumed as its young shoots and leaves. The iron content of young shoots are better than in mature plant tissues. It also had the highest quantity among all leaves in the study.

Minor mineral compositions of the leafy vegetables included arsenic, copper, chromium, selenium and zinc while antimony and tin were detected in traces <0.05mg/Kg as shown in Table II.

Cadmium, lead, and mercury were not detectable in any of the leafy vegetables. Mature leaves of *Chenopodium album* was found to be richer in all the major elements while zinc and copper were rich in young shoots. It may be noted here that the indigenous leafy vegetables compared well with the exotic leaves. Iron content of *Chenopodium album* young shoots was higher than others in the study. The presence of zinc and selenium in these vegetables are important as they are components for the functioning of many antioxidant enzymes. Arsenic concentrations in all four leafy vegetables ranged from 1.5 -1.9mg/Kg DW.

Arsenic together with fluorine are currently recognized as the most widely spread naturally occurring inorganic contaminants associated with ground water [7]. Approximately two thirds of rural water supply utilizes ground water and it is reported that rural water supply systems located in geological units are known or suspected to contain natural sources of contaminants in different concentrations. Some of these constituents like arsenic may be toxic to humans and Livestock if present even in low concentrations. The presence of selenium may be viewed positively as this may contribute to the antioxidant properties reported for the plants.

TABLE II. MINOR MINERALS OF THE SELECTED VEGETABLE (MG/KG) DW

Element	*C. Album*[y]	*C. Album*[m]	*B. oleracea*	*S. nigrum*	*B. rapa*
As	1.8±0.1	1.8±0.1	1.5±0.2	1.9±0.2	1.6±0.04
Cu	14.0±1.0	9.1±0.6	5.6±0.2	11.2±0.4	9.9±0.1
Cr	0.90±0.0	0.90±0.0	2.50±0.0	0.94±0.0	1.20±0.0
Se	5.4±0.0	5.4±0.0	4.4±0.03	5.7±0.0	4.8±0.0
Zn	26.2±1.2	23.0±1.9	26.1±0.9	19.4±1.3	23.9±1.1

[y]Young shoots , [m]Mature plant with flowers, DW dry weight
Data are means±SD of duplicate determinations for each nutrient

VI. DISCUSSION

South African rural households suffer from micronutrient deficiencies as a result of simplified carbohydrate rich staple diet. Lack of diet diversity due to inadequate inclusion of diverse food items is one of the major challenges faced by this population. In this context indigenous leafy vegetables once served the rural poor is a solution in providing the minerals, vitamins and other protective bioactive compounds. The two ILVs reported in this paper (*C album and S nigram*) compared well with the exotic cultivated vegetables (*B oleracea and B rapa*) in micronutrient quality and quantity [8]-[10]. Levels of iron, selenium and zinc in *C album* was promising. In a recent study on *C album* from India Pandey & Gupta [11] reported the presence of iron and zinc while selenium and arsenic were non-detectable. The results point to the fact that presence of toxic components like arsenic depend on the soil not on the plant species. *C album* has been studied extensively for its medicinal properties [11], [12] particularly its antibacterial properties.

The only concern observed in the current study is the presence of toxic element arsenic in both indigenous and exotic leafy vegetables analyzed. Arsenic is a naturally occurring toxic metal found in almost all environments. Its presence in food could be a potential risk to both humans and animals [13]. Arsenic exerts its toxicity by inactivating many enzymes particularly those involved in cellular energy metabolism, DNA synthesis and repair. Acute poisoning is associated with nausea, vomiting, abdominal pain, severe diarrhea, encephalitis and peripheral neuropathy. Chronic toxicity can result in multisystem disease including carcinogenesis affecting many organs [14]. Arsenic has been classified by the International Agency for Research in to Cancer (IARC) as a human carcinogen on the basis of incidence of cancers at several sites in people exposed to arsenic at work or through their diet [15]. Arsenic has been implicated in skin disorders (hyper pigmentation, depigmentation, keratosis and skin cancers), cardiovascular problems (peripheral vascular disease), respiratory and neurological diseases [16]-[18]

Arsenic occurs in several speciation states in soil, water and plants [19] In addition to its presence in geological sources anthropogenic activities such as mining, agriculture (through the use of pesticides) and non- agricultural activities contaminate soils with arsenic. Several factors influence the solubility and speciation of arsenic in the soil. pH, redox potential of the soil, content of organic matter, soil microbes and presence of some elements like iron, phosphorous and calcium of the soil are important factors in this [20]. Studies in laboratory animals demonstrated that toxicity of arsenic depend on its form and oxidation states. It is generally recognized that the soluble inorganic arsenicals are more toxic than the organic ones [21]. Inorganic arsenic is methylated in hepatocytes and thought to be a detoxification mechanism. But it is increasingly recognized as a pathway of inorganic arsenic activation. Methylated forms are more cytotoxic, genotoxic and potent inhibitors of some enzymes than inorganic arsenic [22], [23]. Speciation analysis of arsenic in some vegetables demonstrated that root, shoot and leaf tissues contained only inorganic arsenic with no organic species where as arsenic in seafood is mostly organic and is less toxic than the inorganic species [19], [24].

Arsenic bearing minerals are reported to be associated with geologic settings where sulphide mineralization has taken place. Arsenic is mainly present in areas where gold, silver, zinc, lead and cobalt are found. South Africa being rich in minerals such deposits are wide spread throughout country [25] The above authors have reported arsenic concentrations ranging from 0.01 – 0.1mg/l in ground water from boreholes in South Africa. In their study 20% of the total borehole water analyzed had arsenic concentrations exceeding WHO limits of 0.01mg/l. South African target water quality guideline is 10ug/l and up to 200ug/l is considered a tolerable concentration. Kootbodien *et al.* [26] reported the detection of high levels of arsenic in school vegetable garden soils and arsenic in vegetables grown in these gardens in Johannesburg area of South Africa.

V. CONCLUSION

Micronutrient quality of the indigenous leafy vegetables compared well with the exotic cultivated ones. Detection of the presence of arsenic in both indigenous and exotic leafy vegetables is a cause for concern considering the toxic effect arsenic exposure can have on humans and animals. Further detailed studies are recommended to elucidate the extent of arsenic contamination in both indigenous and exotic vegetables grown in the area as well as vegetables available in the retail shops, Speciation studies of arsenic in the soil and food items grown in the area is also recommended. The fact that trace constituents are relatively common in South African rocks suggests that their distribution mobilization as well as contamination in food should be of concern. The affinity of arsenic, selenium and other non-metals with gold, copper, nickel and other ores suggests that trace constituents can be wide spread in South Africa. Arsenic and selenium unlike most other toxic metals and metalloids are easily dissolved through a wide range of pH and redox conditions also warrant an assessment of the distribution and contamination of food grown in the area.

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