

Analysis of Beetroot Bulbs (*Beta vulgaris*) from Selected Geographical Regions in Kenya: Essential Nutritional Elements Contents

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To cite this article:

Grace Ndunge, David Njoroge Kariuki, Michael Josiah Mangala, Michael James Gatari. Analysis of Beetroot Bulbs (*Beta vulgaris*) from Selected Geographical Regions in Kenya: Essential Nutritional Elements Contents. *Journal of Food and Nutrition Sciences*.

Vol. 8, No. 4, 2020, pp. 112-116. doi: 10.11648/j.jfns.20200804.17

Received: July 21, 2020; Accepted: August 4, 2020; Published: August 13, 2020

Abstract: In Kenya, beetroot bulbs are occasionally used as a blend in fruit juices and salads, as a livestock feed and for treatment of diseases. Analysis of essential elements in beetroot bulbs was performed using Energy Dispersive X-ray fluorescence (EDXRF) in order to determine the nutritional content of the bulbs. The beetroot bulbs were sampled from five different geographical regions in Kenya; Karatina, Gilgil, Naivasha, Joska and Kisumu. The results of the concentrations of the essential elements had a range of: 10000 mg kg⁻¹ to 61000 mg kg⁻¹ for potassium, 500 mg kg⁻¹ to 4500 mg kg⁻¹ for calcium, 15.0 mg kg⁻¹ to 230 mg kg⁻¹ for manganese, 24.0 mg kg⁻¹ to 770 mg kg⁻¹ for iron and 16.0 mg kg⁻¹ to 680 mg kg⁻¹ for zinc. In general, the trend in the concentrations of the essential elements was K > Ca > Fe > Mn > Zn. Karatina samples registered the highest concentrations for all the elements of interest in this study. The results of analysis of variance (ANOVA) for all the five sampled regions show that there is a significant difference in the Ca, Fe and Mn concentration levels. Beetroots were found to contain sufficient amounts of the essential elements, therefore, are a suitable vegetable source of essential elements of K, Ca, Mn, Fe and Zn and can be used as an immune system booster. This study is supportive to the Government's efforts of improving health care and in the fight against "hidden hunger-malnutrition" in the country.

Keywords: Kenyan Beetroot Bulbs (*Beta vulgaris*), Energy Dispersive X-ray Fluorescence, Essential Nutritional Element Content

1. Introduction

Beetroot bulb is the taproot part of a beet plant which is among one of the several cultivated varieties of *Beta Vulgaris*. The usage of beets dates back from the third millennium BC as evidenced by Neolithic site of Aartswoud in the Netherlands and in the Saqqara pyramid at Thebes, Egypt [1]. In Kenya, beetroot is among the horticultural export products to the European Union. The total horticultural export as of 1990 was 125.1 metric tons with a value of USD 133.4 million [2].

Various health benefits are associated with beetroots; reduce blood pressure in hypertensive patients, and in reducing instances of cardiovascular diseases [3]. Sports

endurance performance has also been found to improve with dietary nitrate supplementation that is found in beetroots [4].

Malnutrition cases and nutritional related diseases have been on the rise in Kenya. Nearly 73,000 children and 40,000 pregnant and nursing women in Kenya are severely malnourished and at risk of dying from drought-related hunger [5]. Common sources of essential minerals and vitamins to mitigate malnutrition are vegetables including beetroots.

In Kenya, beetroot is not a popular crop for consumption as it's taste and deep colour may have led to a bias against it. It is therefore crucial to have information on the nutritional value of beetroot bulbs since there are no studies conducted on essential elemental content of beetroots in Kenya.

2. Materials and Methods

2.1. Samples

The samples consisted of thirty-four (34) beetroot bulbs sampled from different geographical regions in Kenya. Out of the thirty-four bulbs sampled, twelve (12) were from Karatina, nine (9) from Gilgil, seven (7) from Naivasha, four (4) from Joska and two (2) from Kisumu. Carrot and potato bulbs were also collected for comparison purposes. The soil types for Karatina, Gilgil, Kisumu, Joska and Gilgil are clay soil, red volcanic, black cotton, loam and red volcanic, respectively.

2.2. Instruments

The spectrometers used in this study were Rigaku NEX CG bench top EDXRF and the AMPTEK EXP-1 EDXRF. The NEX CG is equipped with five secondary targets; RX9, Cu, Mo, Si and Al, that measure elements from Na - U. For improved accuracies on elemental analysis, a specialized light element optimization (LEO) secondary target is also available. A high performance SDD (Silicon Drift Detector), is utilized to realize high analytical precision and accuracy [6]. The AMPTEK EXP-1 EDXRF constitutes the X-ray SDD detector and its preamplifier. The PX4 constitutes three main parts: shaping amplifier, multichannel analyser and power supply. The Mini-X is an X-ray tube system that constitutes a 40 kV/100 μ A power supply, X-ray Mo tube, USB provision for

communication between computer and electronics [7].

2.3. Sample Preparation Procedure

All the samples were washed in double distilled water to remove soil and any foreign particles. The samples were sliced into thin slices then dried in the oven at 60°C for 56 hours to constant weight. After drying, the samples were ground into fine powder using a grinder then sieved with a 75-micron sieve.

For each ground sample, an approximate mass of between 0.5 - 0.6 grams were weighed for making pellets for EDXRF analyses. This was placed between two stainless steel dies enclosed in a cylindrical stainless-steel chamber then pressed using the hydraulic press at 10 kPa to make thin pellets that were 25 mm in diameter. Each pellet was accurately weighed, labelled and stored in a Petri dish ready for analysis. For each sample, three pellets were prepared for EDXRF analysis [8].

3. Results and Discussion

3.1. Method Validation

Table 1 shows the results of EDXRF analysis using Rigaku NEX CG bench top of certified reference Materials; Bowen Kale and Soil-5.

Table 1. Experimental and certified *t*-values for reference materials (*mg kg*⁻¹; *n*=3).

Element	Bowen kale			Soil-5 (IAEA- Soil-5)		
	Experimental values	Certified values	T-test	Experimental values	Certified values	T-test
Mn	23±3	15±2	2.5	1100±200	850±37	2.5
Fe	130±5	120 ±15	2.5	51000±1051	45000±1700	2.5
Zn	32.9±1.4	32±3	2.8	490±4	370±84	2.5
Ca	42000±160	41000±2200	2.5	29300±125	22000±110	2.5
K	24000±140	24000±1500	2.5	23700±228	19000±990	2.5

It was observed that the results of the experimental values were within the range of the certified values for all the five essential elements. From the t-test distribution table.

$T_{\text{tab}} (\alpha = 0.05, 2) = 4.3$ whereas from the results obtained, t_{calc} was less than 4.3. In the t-test, if $t_{\text{calc}} < t_{\text{tab}}$, there is no

significant difference between the experimental value and the certified values [9]. This showed that the method was suitable and thus the results were accurate and reliable. Similar findings have previously been indicated for Bowen Kale using EDXRF spectrometer [10].

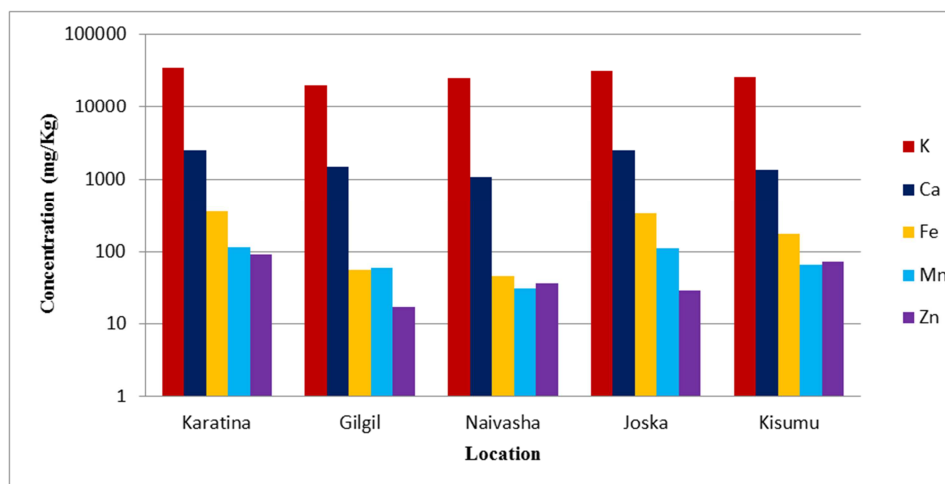


Figure 1. Trends in concentration of elements in all the sites.

3.2. Essential Element Concentration in Beetroot Samples

The variations of elemental concentrations of the samples from different geographical regions are shown in figure 1. There is a uniform trend in the concentrations of K, Ca and Fe in all the sampling sites, where $K > Ca > Fe$. However, for Mn and Zn, the trend of distribution in samples from Karatina, Naivasha and Kisumu is similar but significantly differs from those in Gilgil and Joska. The lowest concentration of Zn ($15.5 \pm 1.2 \text{ mgkg}^{-1}$ - $34.1 \pm 3.3 \text{ mgkg}^{-1}$) was recorded in samples from Gilgil.

In general, all the elements have high concentrations in Karatina samples in comparison to the other regions. This can be attributed to the fact that, Karatina is found in the Kenyan highlands where the soils are deep, have high content of clay, porous and have excellent capacity to hold moisture compared to the other regions. Karatina experiences high annual rainfall approximately 1400 mm thus suitable for planting throughout the year [11].

3.2.1. Potassium

In general, the potassium mean concentration varies between 20000 – 31000 mgkg^{-1} . The results from analysis of variance for all the five sampled regions show that there is no significant difference in the means for potassium, since $F_{\text{calc}} = 2.5 < F_{\text{tabulated}}$, $F_{\text{tab}} = 2.7$.

In the study, “Betainic and nutritional profiles of pigment-enriched red beet root (*Beta vulgaris* L.)” [12] of dried extracts using Inductively Coupled Plasma Atomic Emission Spectroscopy, it was reported that potassium had an average concentration of 13730 mgkg^{-1} which is less than values reported in this study.

The concentration of potassium from the study, “Nutritional value and economic feasibility of red beetroot (*Beta vulgaris* L. ssp. *vulgaris* Rote Kugel)” [13] from different production systems was reported to have an average of 33,766 mg kg^{-1} , which is within the range of what was found in this study. Beetroot contains sufficient potassium levels to contribute to the daily dietary recommended intakes and thus can be recommended as a supplement [14].

3.2.2. Calcium

In this study, the results obtained for the analysis of beetroot samples for the calcium content show that there is a significant difference in the mean values, since $F_{\text{calc}} (6.5) > F_{\text{tab}} (2.7)$. The calcium mean concentrations vary between 1200 – 2800 mgkg^{-1} in the sampled areas.

A study of trace elements in various vegetables that included carrots, broccoli, Muskmelon, spinach and tomatoes, showed that Ca concentrations were 2 - 3%, 1 - 2%, 3 - 5%, 1- 2% and 1- 3%, respectively [15]. However, the calcium levels from this study were lower.

Another comparative study of the accumulation of calcium in different vegetables reported the following; lettuce $95213 \pm 101 \text{ mgkg}^{-1}$, spinach $86606 \pm 102 \text{ mgkg}^{-1}$, hyacinth bean $84615 \pm 79 \text{ mgkg}^{-1}$ and cauliflower $80743 \pm 87 \text{ mgkg}^{-1}$ These values were all higher than those reported in this study [16].

3.2.3. Manganese

The manganese mean concentrations values vary between 36 – 130 mgkg^{-1} in the samples. There is a significant difference in the manganese levels between the samples since $F_{\text{calc}} (5.88) > F_{\text{tab}} (2.7)$.

Manganese levels in some sampled vegetables, *Amaranthus dubius*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Asystasia gangetica*, *Cleome monophylla* and *Oxygonum sinuatum*, reported the concentrations as ranging from 4 $\text{mg}/100 \text{ g}$ - 82 $\text{mg}/100 \text{ g}$ [17].

The concentration of Mn in *Cleome gynandra* (spider plant) and *Beta vulgaris* L, leafy vegetable known as chard or spinach beet, found that *Beta vulgaris* had levels 1.5 times greater than those found in *Cleome gynandra*. However, manganese levels reported in this study were higher, in general [18].

In a study carried out in Finland to analyze changes in the mineral and trace element contents of cereals, fruits and vegetables, it was reported that the concentration of manganese in different root vegetables were; potato 0.7 $\text{mg}/100 \text{ g}$, organic carrot 1.2 $\text{mg}/100 \text{ g}$, beetroot 3 $\text{mg}/100 \text{ g}$, parsnip 1 $\text{mg}/100 \text{ g}$, celery root 1.5 $\text{mg}/100 \text{ g}$, turnip 1 $\text{mg}/100 \text{ g}$, swede 1.1 $\text{mg}/100 \text{ g}$, radish 1 $\text{mg}/100 \text{ g}$ and Jerusalem artichoke 0.2 $\text{mg}/100 \text{ g}$ [19]

In addition, other studies indicate that, the manganese levels were 30-60 mgkg^{-1} , 25-150 mgkg^{-1} , 20-100 mgkg^{-1} , 25-200 mgkg^{-1} and 25-200 mgkg^{-1} for carrots, broccoli, Muskmelon, spinach and tomatoes, respectively. The manganese levels in this study were comparable and within the ranges [15].

The daily recommended intake for manganese for adults is 2-5 mg/day and 2-3 mg/day for children and beetroot is a suitable supplement [14].

3.2.4. Iron

There is a significant difference in the mean values for iron concentration, since $F_{\text{calc}} (14.22) > F_{\text{tab}} (2.7)$, following ANOVA analyses of the samples.

In this study, the mean iron content in beetroot samples range between 53 - 420 mgkg^{-1} , are higher than those reported in a study done in Uganda on iron and zinc content of selected foods in the diet of school children in Kumi District, East of Uganda, where they reported a mean of 50 mgkg^{-1} in cassava, 140 mgkg^{-1} in Irish potatoes and 56 mgkg^{-1} in sweet potatoes [20].

Other studies have determined the mean iron content for roots to be 225 mgkg^{-1} , 74.3 mgkg^{-1} for barks, 195.4 mgkg^{-1} for fruits and 333 mgkg^{-1} for seeds, in plant samples and mean concentration of 71 μgg^{-1} - 280 μgg^{-1} in beans from Cali, Colombia [21-22]. The concentrations of iron in different root vegetables are reported as; potato 3.4 $\text{mg}/100 \text{ g}$, organic carrot 3.4 $\text{mg}/100 \text{ g}$, beetroot 2.9 $\text{mg}/100 \text{ g}$, parsnip 3 $\text{mg}/100 \text{ g}$, celery root 5.5 $\text{mg}/100 \text{ g}$, turnip 4 $\text{mg}/100 \text{ g}$, Swede 3.4 $\text{mg}/100 \text{ g}$, radish 6.5 $\text{mg}/100 \text{ g}$ and Jerusalem artichoke 1.8 $\text{mg}/100 \text{ g}$. These concentrations are all lower than those reported for beetroot in this study [19].

Iron is an essential nutrient in the body that plays an important role in transporting oxygen and carbon dioxide in the blood, preventing and treating anaemia, reducing heart failure and improving thinking and memory [23]. The dietary requirement of iron varies with age and sex. Boys and girls need the same amount of iron, about 10 mg/day from ages 4 to 8, and 8 mg/day from ages 9 to 13. Women need more iron, 18 mg of iron per day from ages 19 to 50 because they lose blood each month during their menstrual periods, while men of the same age require 8 mg/day [24]. In general, beetroot is a good source of iron for daily dietary intake.

3.2.5. Zinc

The results of zinc concentration levels vary between 14.0 mgkg⁻¹ to 680 mgkg⁻¹ in all the beetroot samples, sampled in this study.

The ANOVA results show that there is no significant difference in the means since $F_{\text{calc}} (1.13) < F_{\text{tab}} (2.7)$.

In the evaluation of black tea, for mineral content, the zinc concentrations range between 0.2 - 1.5 mgkg⁻¹ [25]. A study conducted on vegetables and fruits cultivated around the surroundings of Tummalapalle Uranium mining site reported zinc concentration of 4.1±0.8 mgkg⁻¹ for tomatoes, 8.5±6.5 mgkg⁻¹ for green chilli, 5.2±0.8 mgkg⁻¹ for bitter gourd,

4.5±2.9 mgkg⁻¹ for bananas, 7.3±5.1 mgkg⁻¹ for papaya and 9.2 ± 4.2 mgkg⁻¹ for melons. These concentrations are low, when compared to those obtained for beetroot samples in this study [26]. However, the zinc levels in *Amaranthus dubius*, *Amaranthus hybridus*, *Amaranthus spinosus*, *Asystasia gangetica*, *Cleome monophylla* and *Oxygonum sinuatum*, are reported as ranging from 5 mg/100g - 56 mg/100g, are higher than the zinc concentration levels in beetroot reported in this study [18].

The concentration of zinc in different root vegetables elsewhere, are reported as; potato 1 mg/100 g, organic carrot 2.1 mg/100 g, beetroot 1.6 mg/100 g, parsnip 2.1 mg/100 g, celery root 3.7 mg/100g, turnip 2.4 mg/100 g, swede 1.9 mg/100 g, radish 3.1 mg/100 g and Jerusalem artichoke 1.4 mg/100g [19]. The daily dietary requirement for zinc is 4.2 – 14 mg/day [14].

3.3. Comparison of Beetroot, Moringa (*M. oleifera*), Potatoes and Carrots

Table 2 shows the results of concentration levels of trace elements of interest in this study, for potatoes, moringa and carrots and beetroot for comparison.

Table 2. Concentration of Different Vegetables in mg Kg⁻¹.

Type	Mn	Zn	Fe	Ca	K
Beetroot	90 ±15	64±8	230±27	2100±250	32000±1600
Potato	15±2	134±1	53±3	420±28	28000±1500
Moringa	89±5	24±1	370±17	19000±110	24050±140
Carrot	29±5	31±3	140±4	6800±440	44000±2500

The concentrations levels for all the elements in beetroots are high, except calcium, where moringa and carrots has eight times and three times higher, respectively. In addition, the concentration of iron in moringa samples is higher than that of beetroot. Thus, is a good source of potassium, calcium, manganese, iron and zinc.

4. Conclusion

Cases of malnutrition and nutritional related diseases have been on the rise in Kenya, thus bringing forth the need for research to be carried out on assessing the nutritional value of different vegetables, fruits and food crops in general that constitute a diet.

This study determined the levels and variations of essential elements in beetroots sampled from Karatina, Gilgil, Naivasha, Joska-Machakos and Kisumu. The elemental concentrations were measured using Energy Dispersive X-ray Fluorescence spectrometer.

The results of the concentrations of the essential elements had a range of: 10000 mg kg⁻¹ to 61000 mg kg⁻¹ for potassium, 500 mg kg⁻¹ to 4500 mg kg⁻¹ for calcium, 15.0 mg kg⁻¹ to 230 mg kg⁻¹ for manganese, 24.0 mg kg⁻¹ to 770 mg kg⁻¹ for iron and 16.0 mg kg⁻¹ to 680 mg kg⁻¹ for zinc. In general, the trend in the concentrations of the essential elements was K >Ca > Fe >Mn> Zn. Karatina samples

registered the highest concentrations for all the elements of interest in this study.

In general, the concentrations of essential elements in beetroots are higher than those found in most commonly consumed tubers and leafy vegetables. Beetroots were found to contain sufficient amounts of the essential elements, therefore, are a suitable vegetable source of essential elements and can be used as an immune system booster.

Acknowledgements

I am thankful to the University of Nairobi for offering me the scholarship to do MSc studies in Nuclear Science. I also appreciate the support of laboratory staff; Simion Bartilol, Chief Technologist, Institute of Nuclear Science and Technology, Justus. Okonda, Department of Physics, J. W. Macharia and E. Mwangi, Department of Chemistry, all from the University of Nairobi for their assistance in carrying out laboratory analysis for this study.

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