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Assessment of essential trace elements in selected food grains, herbal spices and seeds commonly used in Kenya

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Trace elements are essential in preserving good health and body immunity to diseases. The study was undertaken to determine the levels of chromium (Cr), vanadium (V), selenium (Se) and zinc (Zn) in herbal spices, food grains and edible seeds commonly used in Kenya. The levels of elements were determined using atomic absorption spectroscopy (AAS). The herbal spices, food grains and seeds considered in this study included coriander (*Coriandrum sativum*), ginger (*Zingiber officinalis*), garlic (*Allium sativum*), cloves (*Syzygium aromaticum*), lemon grass (*cymbogon citratus*) rosemary (*Rosmarinus officinalis*), wheat (*Triticum cestivum L.),* brown rice (*Oryza sativa*), finger millet (*Elusine coracana*), bulrush millet ((*Pennisetem glaucum*), sorghum (*Sorghum bicolor*), sunflower seeds (*Helianthus anuus)*, watermelon seeds *(Citrullus lanatus)* and pumpkin *(Cucurbita maxima*) seeds. The results indicated that lemon grass had the highest V levels (14.40±1.20 mg/kg) followed by ginger at (14.38±0.31 mg/kg) while coriander seeds had the highest Cr levels (13.00±0.42 mg/kg), followed by lemon grass (12.80±1.47 mg/kg). Bulrush millet had the highest Se levels (198.38±3.75 µg/k) followed by sorghum (151.20±12.8 µg/kg). Pumpkin seeds had the highest level of Zn (53.54±1.44 mg/kg) followed by watermelon seeds at 41.00±5.79 mg/kg. The food grains, seeds and herbal spices could provide the body with the required daily intake. Consumption of mixed diet could therefore provide the body with essential trace elements that could boost the body immunity especially to those people with compromised health.

Key words: Trace elements, nutrition, herbal spices, food grains, fruit seeds, AAS.

INTRODUCTION

Good nutrition is essential for achieving and preserving health while helping the body to protect itself from infections (WHO and FAO, 2002). Vitamins and minerals are essential for good health for the body against opportunistic infections by ensuring that the lining of the skin, lungs and gut remain healthy and that the immune system functions properly (WHO and FAO, 2002). Trace elements such as selenium, zinc, chromium and vanadium play a major role in improving the body immunity against diseases (Al Durtsch, 1999; American

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Cancer Society, 2004). Available and reliable sources of these minerals in terms of absorption are plant sources. Plants absorb much of the essential elements from the soil in which they grow. Herbal spices and food grains contain essential trace elements in amounts that are helpful to the body. In spite of advances in diagnosis and treatment, cancer continues to be a major health burden (American Cancer Society, 2004). With the fear associated with diagnosis of cancer, it is not surprising that the public may have considerable interest in easily implementable measures such as use of vitamins and trace element supplements for cancer prevention. Selenium is effective in cancer reduction because it prevents development and progression by causing cancer cells to die before they can have a chance to grow and spread in a process called apoptosis (American Cancer Society, 2004). Selenium is also said to preserve elasticity in body tissue, slow aging process, improve the flow of oxygen to the heart, prevent abnormal blood clotting and stimulate the formation of antibodies in response to vaccines (American Cancer Society, 2004). Selenium is an excellent anti-oxidant. Various studies have shown that people with epilepsy have significant low levels of selenium and supplementation with selenium results in fewer seizures (Mahyar, et al., 2010). Zinc in the diet can greatly reduce cases of malaria, diarrhoea, pneumonia and other infections (Fox, 1998). These diseases are the major killers of children all over the world. Zinc is essential for human body growth and development of normal brain function. It is a component of many enzymes and thus involved in numerous metabolic processes (Rink and Gabriel, 2000). It is an important co-factor of important enzymes such as DNA, RNA and protein synthesis and so on, is important for cell division (Hambidge et al, 1986). It plays an important role in the protection of cell membrane integrity and may be protective against free radical injury (Prasad, 1983).

Replacing complex carbohydrates with refined simple carbohydrates (white flour and sugar) will eventually wear out chromium supply and possibly cause diabetes (Al Durtsh, 1999). Chromium is found in tiny amounts in the body and has the main function of glucose metabolism. Insulin, a hormone that controls blood sugar cannot function without glucose tolerance factor (GTF) and the molecule contains chromium. Chromium is also required by pregnant mothers to build the babies stock to last them up to 10 years of age when they start ingesting Cr (Al Durtsh, 1999). Vanadium is essential in humans, as it helps to promote healthy glucose levels in people with lack of insulin sensitivity. It also plays a role in building healthy bones and teeth as well as promoting healthy cellular replication in the body (Cohen et al., 1995).

There is great interest in healthy benefits of whole grain foods like brown rice, millets sorghum, whole wheat and spices in countries around the world. Hence, this study was done to: (1) analyse some essential trace elements in selected food grains and spices, and (2) compare with recommended daily in intake (RDI).

MATERIALS AND METHODS

Sampling

The herbal spices, grains and edible seeds were obtained from supermarkets, open air markets and agrochemical shops in the Central Business District (CBD), Nairobi city, Kenya. The pumpkin and watermelon seeds were freshly scooped from the fruits, washed and dried. All the samples were dried in the oven at 80°C to a constant weight and ground using a laboratory mini miller (Glen Crescent Company, England) and homogenized to make a representative sample. The samples were finally put in clean polythene bags, labeled and stored safely awaiting analysis in the laboratory. For zinc, analysis was done at Government Chemist laboratory using AAS model AA-668 (Shimadzu, Japan) while analysis of vanadium, selenium and chromium was done at Mines and Geology laboratory using AAS VGA-77 Model (Varian, Australia).

Chemicals and reagents

All chemicals and reagents used in this research were of analytical grade. Nitric acid, sulphuric acid and perchloric acid were sourced from Thomas Baker Chemicals Ltd. Mumbai India whereas hydrochloric acid and sodium hydroxide were from Sd. Line Chem. Lab. Mumbai India. Sodium hydroxide was from Sigma Aldrich Chemi Kallen GmbH, United States. The standards (Zn, Se, Cr and V) were prepared by serial dilution of commercially pre-prepared stock solutions purchased from Fluka Chemie GmbH Aldrich Chemical Company, Inc. USA. The stock solutions were in 1% nitric acid with concentration of 1000 µg/ml.

Cleaning of glassware and plastic containers

All glassware were cleaned with detergent and hot water, rinsed several times with tap water and then soaked for several hours in 10% nitric acid solution. Finally they were rinsed thoroughly with distilled deionized water, dried in the oven at 105°C and then stored in clean and dry drawers. The plastic bottles were cleaned with detergent and tap water, soaked with 1:1 nitric acid overnight and rinsed with distilled deionized water and then dried on open racks.

Sample preparation for AAS

A 2.0 g sample was weighed and placed in a 250 ml Kjeldhal flask and digested with 27 ml mixture of HNO_3, H_2SO_4 and $HClO_4$ in the ratio of 6:3:1 (Horwitz, 2001; Khan et al., 2011). The digest was cooled and filtered using Whatman No. 42 filter paper into 100 ml volumetric flask and then diluted to the mark with distilled deionized water. The sample was then transferred into a plastic bottle. A blank was prepared in the same way as the samples. Standards containing known concentrations of the elements were prepared from pre-prepared stock solutions by serial dilutions. Using values for standards, a calibration curve was obtained and used to quantify the trace element levels in the digested samples and blank. The samples were analysed in triplicates. Samples, standards and blank were analysed against calibration curve for each element (Figure 1) under same conditions using AAS (Horwitz, 2001; Khan et al., 2011). The operating conditions of the AAS (Shimadzu model AA-668) are given in Table 1. Selenium was analysed using a hydride generator (Varian Model VGA-77) connected to AAS (Model Spectra AA-10, Varian, Australia).

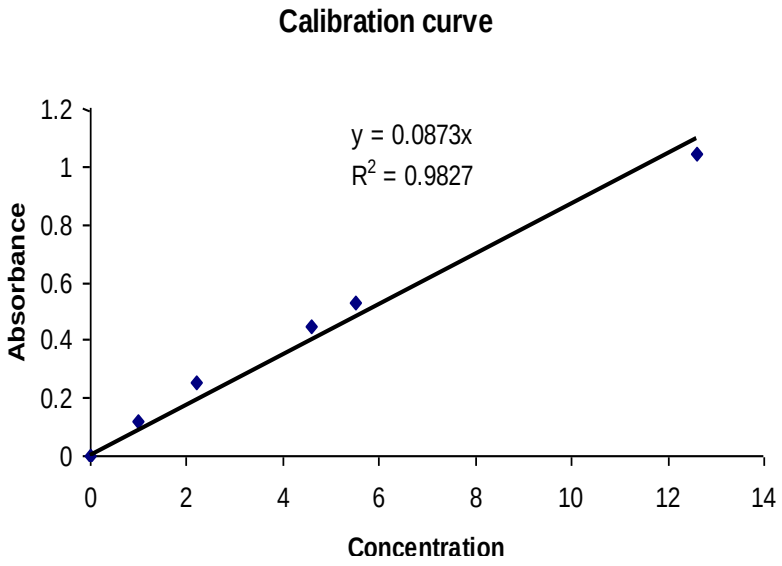

Figure 1. Zn Calibration curve

Table 1. Atomic absorption spectroscopy (AAS) operating conditions.

Parameter	Cr	Zn	Se	V
Wavelength (nm)	357.9	213.9	197	318.5
Slit width (nm)	0.2	1.0	1.0	0.2
Flame	Air/Acetylene	Air/Acetylene	Air/Acetylene	No_2/Acetylene
Oxidant flow rate (Litres/min)	1.5	1.5	1.5	4.5
Detection limit	0.02 mg/kg	0.01 mg/kg	0.03 µg/kg	0.02 mg/kg
Sensitivity	0.015	0.01	0.02	0.4

Calibration curves

Calibration curves (Figures 1-4) from the standards (Zn, Se, Cr and V) were used to determine the concentrations of the trace elements in the samples. The Zn, V and Cr, concentration was indicated in mg/kg while that of Se was given in µg/kg. To eliminate some of the errors associated with a single measurement, the working curve method was used. A working curve was prepared by plotting absorbance of solutions of standards of the trace elements as a function of their concentration. The standard solutions that were used to prepare the working curve had a broad range of concentrations to encompass the measured absorbance of all sample solutions.

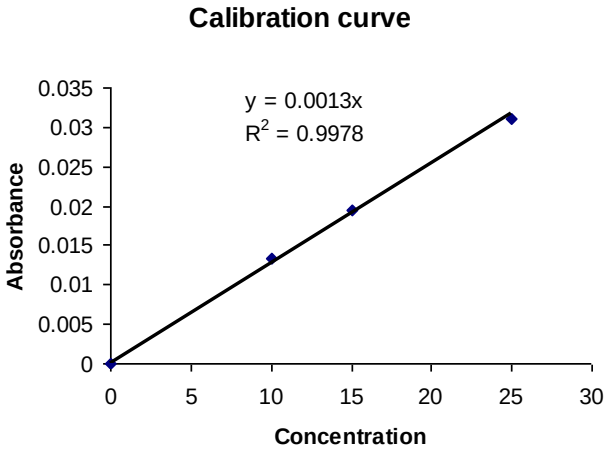

Figure 2. Se calibration curve

RESULTS AND DISCUSSION

The results of all food items analyzed for Zn, Se, Cr and V are shown in Table 2. The results indicate that the samples considered in this study have the trace elements V, Se, Cr and Zn though the amounts varied from sample to sample.

Zinc levels varied from 10.9±0.39 in Rosemary to 53.54±1.44 in pumpkin seeds. Zinc levels were found to be the highest in pumpkin seeds (53.54±1.44 mg/kg), followed by watermelon and sunflower seeds respectively. There is significant difference ($p<0.05$) in the Zn levels in pumpkin and sunflower seeds but no

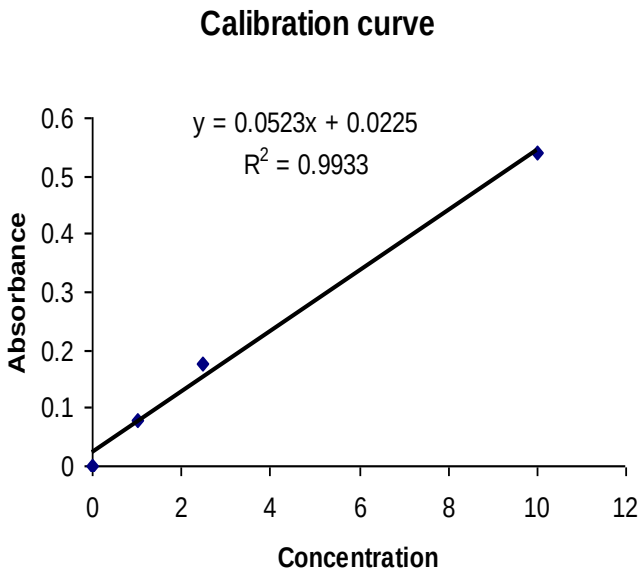

Figure 3. Cr calibration curve.

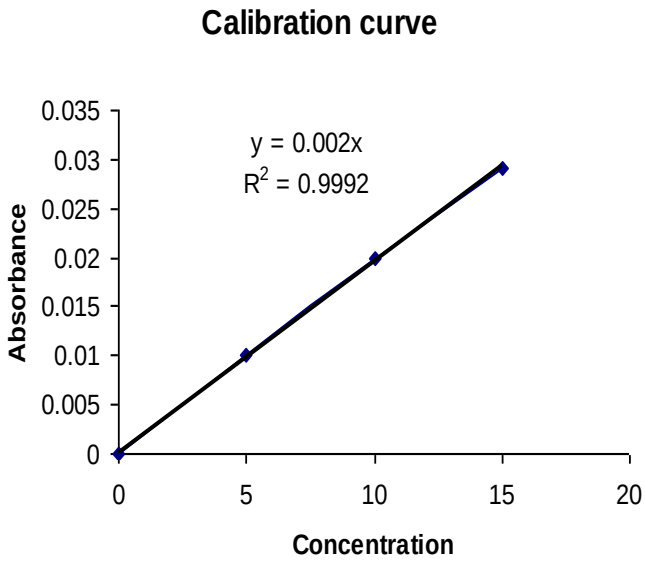

Figure 4. V calibration curve.

significant difference in Zn levels found in pumpkin and watermelon seeds. Among the grains, bulrush millet had the highest level of Zn (28.78 ± 0.65) while sorghum had the lowest level. Among the spices, coriander seeds had the highest level of Zn at 34.5 mg/kg. Zinc is the component of more than 270 enzymes and its deficiency in the organism is accompanied by multisystem dysfunction (Zinpro, 2000). It is responsible for sperm manufacture, fetus development and proper function of the immune response (Serfor et al., 2002). Zinc plays a role in the synthesis and degradation of carbohydrates, lipids, proteins and nucleic acids (Hambidge et al., 1986). Severe Zn deficiency effects include impaired reproduction, immune disorders, dermatitis and impaired wound healing, night blindness, poor appetite, liver cirrhosis, enhanced sensitivity to drugs, most of which are treatable with adequate amounts of Zn (Walsh et al., 1994). This indicates that a mixed diet of the fruit seeds, food grains and spices are a good source of zinc and their consumption could be encouraged to individuals with low levels of zinc. The RDI levels of zinc are 2.5-9.4 mg/kg (Giridhar et al., 2013).

Selenium was highest in bulrush millet (198.38 µg/kg) followed by watermelon seeds, ginger, garlic and sorghum respectively. The lowest level was in brown rice with 27.73 µg/kg. There is no significant difference ($p>0.05$) in the levels of selenium in bulrush millet and watermelon seeds. However, bulrush millet is commonly consumed by a larger population of Kenyans as part of diet but unfortunately, the watermelon seeds are thrown away as people consume the fresh juicy part. The spices are consumed in small amounts but they are believed to have a therapeutic effect. Selenium improves sperm motility and hence human reproduction (Hawkes and Turek, 2001). It is also an essential co-factor of antioxidant enzyme such as glutathione peroxidase (Zhang et al., 1999) and its deficiency has been associated with cardiovascular diseases, diabetes, arthritis (Stranges et al., 2006; Coppinger and Diamond, 2001). It has also been shown to have protective role against cancers such as prostrate (Bjelakovic et al., 2004; Yu et al., 1997) and to improve immune function (Broome et al., 2004). Deficiency of selenium causes hair loss, skin and fingernail discoloration, low immunity and fatigue. Increasing selenium level intake improves immune function when body stores are not at an optimal level (Broome et al., 2004). The bulrush millet, sorghum, watermelon seeds and spices such as garlic and ginger have selenium levels, which could provide the recommended daily intake. The required daily intake of Se is 55 µg for health adults with 40 µg being the minimum requirement while a daily dose of 100-200 µg inhibit genetic damage and cancer development in humans because a methylated form of Se is necessary for cancer reduction (Whanger, 2003).

Vanadium was found to be highest in lemon grass (14.4 mg/kg) followed by ginger 14.38 mg/kg, cloves 13.60 mg/kg and coriander seeds (12.4 mg/kg) respectively. There was no significant difference between levels of vanadium in lemon grass and ginger at $P= 0.05$. Vanadium levels were found to be higher among the spices studied (11.8-14.4 mg/kg) and therefore recommended for use in food preparation. Vanadium is used for treating diabetes, high cholesterol, heart disease, tuberculosis, syphilis, anemia, water retention (edema) and for improving athletic performance in weight training; and for preventing cancer (Cusi et al., 2001; Guo et al., 2010; Samantha, 2008). It is believed to prevent

Table 2. Amount of trace elements present in the food grains, herbal spices and seeds

Food item	Zn (mg/kg)	Se (µg/kg)	V (mg/kg)	Cr (mg/kg)
Brown rice	19.2 ± 1.16	27.73 ± 1.68	5.76 ± 0.51	2.24 ± 0.28
Wheat	27.29 ± 2.61	140.69 ± 5.7	11.48 ± 1.32	5.69 ± 0.34
Finger millet	19.0 ± 0.82	91.38 ± 5.68	9.58 ± 0.56	2.32 ± 0.54
Bulrush millet	28.78 ± 0.65	198.38 ± 3.75	6.28 ± 0.6	2.70 ± 0.38
Sorghum	17.89 ± 2.33	151.2 ± 12.8	7.23 ± 1.18	5.86 ± 0.27
Garlic	18.9 ± 0.77	151.9 ± 11.90	8.1 ± 0.58	1.76 ± 0.25
Ginger	20.5 ± 2.37	153.9 ± 0.90	14.38 ± 0.31	10 ± 1.01
Rosemary	10.9 ± 0.39	96.2 ± 3.9	11.80 ± 1.50	4.25 ± 0.75
Cloves	27.07 ± 4.9	30.1 ± 6.30	13.60 ± 1.20	4.6 ± 0.80
Lemon grass	31.30 ± 0.81	110.7 ± 15.20	14.4 ± 1.2	12.80 ± 1.47
Coriander seeds	34.50 ± 0.71	82.7 ± 16.3	12.4 ± 2.5	13.0 ± 0.42
Pumpkin seeds	53.54 ± 1.44	16.54 ± 1.02	1.54 ± 0.17	5.26 ± 0.57
Watermelon seeds	41.00 ± 5.79	182.70 ±13.2	8.50 ±1.15	6.20 ± 1.11
Sunflower seeds	36.8 ± 0.74	36.50 ± 3.26	10.53 ± 1.31	5.0 ± 1.29

Table 3. Comparison of t-critical for Zn, Se, Cr and V.

Food item	Mean levels of Zn (mg/kg) (n=10)	Zn t-value at P=0.05	Mean levels of Se (µg /kg) (n=10)	Se t-value at P=0.05	Mean levels of Cr (mg/kg) (n=10)	Cr t-value at P=0.05	V mean levels in mg/kg (n=10)	V t-value at P=0.05
Brown	21.01 ±1.21	15.70	27.73 ± 1.68	-51.32	2.24 ± 0.28	23.04	6.61 ± 0.97	21.52
Wheat	30.95 ± 1.23	25.34	140.69 ± 5.7	47.54	5.68 ± 0.34	50.96	11.47 ± 1.32	27.45
Finger millet	21.80 ± 0.82	17.48	91.38 ± 5.68	20.25	3.00 ± 0.26	34.06	9.58 ± 0.56	54.04
Bulrush millet	32.44 ± 0.70	78.78	198.38 ± 3.75	23.77	2.79 ± 0.44	18.61	6.28 ± 0.60	33.05
Sorghum	21.01 ± 2.3	8.26	151.20 ± 12.80	120.90	5.86 ± 0.27	66.24	8.25 ± 0.74	35.21
Garlic	53.54 ± 1.44	84.63	152.01 ± 11.90	161.46	1.76 ± 0.25	19.73	8.1 ± 0.58	44.11
Ginger	41.00 ± 5.79	14.20	153.81 ± 0.89	351.08	10.00 ± 1.01	30.68	14.38 ± 0.31	146.59
Rosemary	36.80 ± 0.74	93.16	30.07 ± 0.63	-125.14	4.60 ± 0.80	17.39	13.63 ± 1.20	35.92
Cloves	24.68 ± 1.20	25.51	96.22 ± 3.90	33.42	3.78 ± 0.96	11.79	11.80 ± 1.50	24.86
Lemon grass	23.32 ± 2.26	11.64	110.69 ± 15.20	11.86	12.80 ± 1.47	27.10	14.38 ± 1.20	37.87
Coriander	30.00 ± 0.44	10.78	82.71 ± 16.30	5.38	13.00 ± 0.42	96.37	12.38 ± 2.50	15.65
Pumpkin	12.82 ± 0.84	-8.20	16.54 ± 1.02	-120.84	5.26 ± 0.57	28.07	1.54 ± 0.17	28.46
Watermelon	33.30 ± 2.77	20.89	182.70 ± 13.20	30.59	6.20 ± 1.11	17.09	8.50 ± 1.15	23.34
Sunflower	36.84 ± 0.58	119.08	36.50 ± 3.26	-17.94	5.00 ± 1.29	11.76	10.53 ± 1.37	25.39

cholesterol formation in blood vessels and nervous system as well as improving insulin sensitivity and reducing blood sugar in people with type 1 and type 2 diabetes mellitus (Cusi et al., 2001). Vanadium may also be needed for iodine metabolism and/or thyroid function. However, vanadium deficiency causes reduced growth, poor bone development, impaired reproductive capacity and poor teeth development (Kreider, 1999). The spices (lemon grass, ginger, cloves) and coriander seeds as well as wheat are good sources of vanadium, which could provide the body with sufficient levels required to improve and maintain body immunity. The RDI requirement for vanadium is 10 µg/kg (NAS, 1998).

The chromium levels ranged from 13.0-1.76 mg/kg. Chromium was the highest in coriander seeds (13.0 ± 0.42), followed by lemon grass, and ginger respectively. There is no significant difference between Cr levels in coriander seeds and lemon grass. However, both plants are rarely consumed. Chromium is found in tiny amounts in the body and has the main function of glucose metabolism (Table 3). The presence of Cr in plants may be correlated with therapeutic properties against diabetic

and cardiovascular diseases (Perry, 1972). It has been shown to increase humoral and cell mediated immunity (Khangarot et al., 2002). Large amounts of Cr are found in adrenal glands, indicating its importance in the production of stress coping hormones. White blood cells contain Cr and this explains why one is susceptible to illness when under stress, and not able to consume enough of the mineral. Chromium activates vitamin C, and is therefore needed to reap the full benefit from it (Al Durtsch, 1999). Deficiency of Cr causes body fatigue, decrease in energy levels, muscle weakness, slow growth rate in children (Al Durtsh, 1999). Coriander seeds, lemon grass and ginger are good sources of chromium and their consumption could be encouraged to people with the symptoms of its deficiency. The RDI levels of chromium are 50-200 µg/kg (Kumpulainen et al., 1979). A diet of mixed food components would provide the body with the required daily intake (RDI) as indicated in Table 3. Some of the foods analysed in this study are readily available in the market and could be fed on people with compromised immunity.

Conclusion

All the samples analyzed contained the four elements (Zn, Se, V and Cr). The amount varied from sample to sample. Seeds had the highest levels of zinc with pumpkin seeds having the highest level followed by watermelon seeds and sunflower seeds. Herbal spices had the highest level of vanadium with lemon grass and ginger leading. Bulrush millet was found to have the highest levels of Se followed by watermelon seeds, ginger, garlic and sorghum, respectively. Coriander seeds were found to have the highest levels of Cr followed by lemon grass and ginger respectively among others.

Consumption of whole food grains, herbal spices and fruit seeds should be encouraged as good sources of trace elements which boost the body immunity. Recently there have been increases in lifestyle diseases in Kenya such as diabetes, high blood pressure and cancers and considering the cost of treatment is prohibitive, good nutrition is wealth. It is therefore important to encourage people to consume whole grain foods (cereals, pasta, porridge) containing finger millet, bulrush millet, sorghum, brown rice, wheat as part of daily diet as they contain the essential elements and high in fiber. From the results obtained it can be concluded that a mixed diet, would provide the body with the required daily intake of the trace elements as indicated in (Table 3).

Conflict of interests

The authors did not declare any conflict of interest.

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