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Levels of elements in selected food substances that support usage in the management and treatment of erectile dysfunction

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Abstract

Background: The use of fruits and vegetables for the management and treatment of erectile dysfunction has gained popularity due to the cheaper cost, accessibility and perceived absence of side effects. Much of the work done on plant-based aphrodisiacs has focused on the phytochemistry of secondary metabolites. **Aim:** This work sought to analyze selected fruits and vegetables that are commonly used in the management of erectile dysfunction in Ghana and quantify the levels of some micro- and macro-elements necessary for good penile health in order to determine the usefulness or otherwise of the selected produce. **Methods:** Energy-dispersive X-ray fluorescence spectroscopy was used to detect and quantify the levels of potassium (K), calcium (Ca), selenium (Se), magnesium (Mg), iron (Fe), and zinc (Zn) in carrot roots, cucumber fruit, garlic bulb, ginger rhizome, nutmeg fruit, sweet potato tuber, tiger nut tuber and watermelon fruit. **Results:** The analysis revealed the presence of K, Ca, Mg, Fe and Zn. Levels of Se were below detection. The concentration of K was the highest in each of the food substances. However, in terms of recommended daily allowance, Mg had the highest contribution. Cucumber fruit and the rind of watermelon fruit had the highest levels of micro- and macro-elements implicated in erectile dysfunction. **Conclusion:** The potential use of these foods to treat and manage erectile dysfunction may not only be due to the presence of phytochemicals alone but also the presence of significant levels of micro- and macro-elements required for good penile health.

Keywords

Energy-dispersive X-ray fluorescence, erectile dysfunction, food substances, macro-elements, micro-elements, recommended daily allowance

Introduction

Erectile dysfunction (ED) is the persistent inability to develop and/or maintain firm penile erection for penetrative sexual intercourse (National Institute of Health, 1993). ED can adversely affect the quality of a man's life as the inability to perform satisfactorily during penetrative sex can lead to emotional pressures from sexual partner(s). ED has led to breakdown of families due to the lack of intimacy among sexual partners (Li et al., 2016).

ED is ubiquitous and affects men of all ages irrespective of their race or ethnicity. Depending on the methodology employed, target group and sample size, prevalence rate can be 10%–90% (Braun et al., 2000). It is expected that ~322 million of the world's male population will experience ED by the year 2025 (Ayta et al., 1999). The causes of ED could be neuropathic (Nguyen et al., 2017), vasculopathic (Skeldon et al., 2015), and/or endocrinopathic (Holland et al., 2019).

Several orthodox (Mobley et al., 2017) and herbal medications (Afolayan and Yakubu, 2009; Lim, 2017), lifestyle modifications and other forms of therapy (Mobley et al., 2017) are used to manage and treat ED. The high cost, limited availability, inaccessibility especially in lower and

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middle-income level countries, unreliable efficacy due to substandard products, and unpleasant side effects of some allopathic ED medications, however, limit their usefulness (Afolayan and Yakubu, 2009). Some culturally conservative societies frown on discussing sexual matters outside of the bedroom. Hence, men suffering from ED have difficulty in discussing the problem and seeking medical assistance for the fear of stigmatization (Afolayan and Yakubu, 2009, Fiaveh, 2020). Such patients therefore resort to anecdotal remedies within the context of their society and culture to treat themselves. Information on the folkloric treatment of ED has generally been observed to be available through non-medical literature, peers and herbal practitioners, among others.

Consequently, some plant-based food substances such as fruits, vegetables, and spices have been used folklorically to treat ED even in modern societies for many years. These traditional remedies are normally cheaper, readily accessible and perceived to have no side effects since they are obtained from "natural" sources (Afolayan and Yakubu, 2009).

Available research on plant-based aphrodisiac medicines has largely focused on the phytochemistry of inherent secondary metabolites (Shiota et al., 2013). It has however been reported that penile health is also influenced by normal levels of certain micro- and macro-elements systemically (Archer, 2002; Ghofrani et al., 2006; Jeon et al., 2005; Mistry and Kurlak, 2015; Mocchegiani et al., 2013; Tvrda et al., 2015). Some of these micro- and macro-elements affect the vascular, hormonal and neuronal processes leading to penile erection. For instance, deficiency of certain elements such as Ca (Ghofrani et al., 2006), Fe (Tvrda et al., 2015), K (Archer, 2002), Mg (Jeon et al., 2005), Se (Mistry and Kurlak, 2015) and Zn (Mocchegiani et al., 2013) have been implicated in ED. Calcium affects erection by stimulating nitric oxide synthase through the calmodulin pathway (Ghofrani et al., 2006). Nitric oxide synthase catalyses the production of the vasodilator, nitric oxide, from L-arginine. Soluble guanylate cyclase (sGC) then catalyzes the conversion of guanosine triphosphate to cyclic guanosine monophosphate (cGMP), whose high concentration in the body leads to smooth muscle relaxation. However, sGC is only activated through a specific binding interaction of NO with the sGC heme. In addition, iron plays a vital role in spermatogenesis and libido enhancement. Iron deficiency anaemia is strongly correlated to sexual dysfunction as it could lead to oxidative damage of the testicular tissues and defective spermatogenesis (Tvrda et al., 2015). Potassium also facilitates smooth muscle relaxation. The activity of potassium channels in the corporal smooth muscle cell membrane, directly associated with erection, is enhanced by the cAMP or cGMP pathway (Archer, 2002). Activation of these potassium channels results in the efflux of potassium ions from the smooth muscle cells resulting in hyperpolarization, and hence, vasodilation to increase penile blood flow and promote erection (Archer, 2002). Magnesium acts as a testosterone enhancer by facilitating the activity of androgen, estrogen and neurotransmitters that regulate sex drive (Maggio et al., 2014). The M-site of phosphodiesterase-5 enzyme, implicated in ED, is rich in magnesium and zinc (Jeon et al., 2005). Selenium reduces the production of free radicals in the seminiferous tubules of the penis, which results in a reduced tendency of occurrence of vasculogenic ED. Selenium also plays a role in sperm production and regulation of enzymes involved in nitric oxide production such as nitric oxide synthase. Its deficiency has been implicated in penile ED (Mistry and Kurlak, 2015). Zinc stimulates the release of hormones from the pituitary gland that stimulates the production of testosterone (Mocchegiani et al., 2013). A lot of these macro- and micronutrients are claimed to be present in sufficient levels in a number of food substances perceived to have aphrodisiac and ED restorative properties.

For this purpose, the elemental composition of selected fruits and vegetables often consumed as remedy for ED in Ghana such as carrot (*Daucus carota*) roots, cucumber (*Cucumis sativus*) fruit, garlic (*Allium sativum*) bulb, ginger (*Zingiber officinale*) rhizome, nutmeg (*Myristica fragrans*) fruit, sweet potato (*Ipomea batatas*) tuber, tiger nut (*Cyperus esculentus*) tuber and watermelon (*Citrullus lanatus*) were investigated using the energy-dispersive X-ray fluorescence (EDXRF) technique. The objective of the study was to assess the levels of selected elements namely Ca, Fe, K, Mg, Zn and Se, useful for penile erection in the selected produce in order to proffer some scientific justification for their ameliorative use in some forms of ED in Ghana.

Materials and methods

Sample collection, identification and preparation

Carrot roots, cucumber fruit, garlic bulb, ginger rhizome, nutmeg fruit, sweet potato tuber, tiger nut tuber and watermelon fruit were purchased from the open market in Accra, Ghana. The identities of all samples were authenticated by a botanist at the Centre for Plant Medicine Research, Mampong, Ghana and herbarium numbers were generated and assigned as follows: carrot (*Daucus carota*) roots: CPMR 138; cucumber (*Cucumis sativus*) fruit: CPMR 139; garlic (*Allium sativum*) bulb: CPMR 140; ginger (*Zingiber officinale*) rhizome: CPMR 141; nutmeg (*Myristica fragrans*) fruit: CPMR 142; sweet potato (*Ipomea batatas*) tuber: CPMR 143; tiger nut (*Cyperus esculentus*) tuber: CPMR 144 and watermelon (*Citrullus lanatus*): CPMR 145.

All glasswares used were acid-washed and dried in order to avoid contamination. All selected fruit and vegetable samples were washed with deionized water to remove dirt and any extraneous material. Carrot, cucumber, tiger nut and nutmeg were chopped into pieces using a stainless steel cutter and dried in an oven at 40 °C for 1 week to constant weight. The dried samples were pulverized using a

stainless steel blender and stored in a desiccator. Sweet potato, ginger and garlic were peeled before they were chopped, dried and pulverized. Watermelon fruit was washed, chopped into pieces and the seeds, pulp and rind were separated. The seeds and rind were dried in an oven at 40 °C for 1 week after which each was pulverized. The pulp was freeze-dried at −60 °C for 3 d followed by pulverization. All powdered samples were sieved using aluminium test-sieves with a vibratory electronic sieve shaker of 180 μm mesh size (Retsch GmbH, Haan, Germany).

Elemental analysis with EDXRF

EDXRF spectroscopic measurements were carried out with a Vanta M-series ED-XRF Handheld Analyzer (Olympus, Norfolk, USA) using the instrumental set up, experimental conditions and methodology as described by Asiedu-Gyekye et al. (2016). Instrumentation of the ED-XRF spectrometer and the principles of the technique are described elsewhere (van Grieken and Markowicz, 2002). For each food sample, one pellet was formed for the analysis and triplicate measurements were conducted. Three batches of samples were analysed and the average was reported as mg/kg of dry weight (dw).

Data analysis

Data from the EDXRF analysis were entered into Microsoft Excel for statistical analysis. Bar charts were plotted to show the levels of metals in the samples. The contribution to the Recommended Dietary Allowance (RDA) for each metal was calculated for a 4 g dry weight of food sample based on the values for men at 40 years and above as follows:

$$\text{Contribution to RDA} = \frac{\text{amount supplied by consumption of 4 g dw sample}}{\text{RDA}}$$

The RDA values are as follows: Ca = 1000 mg/day, Fe = 8 mg/day, K = 4700 mg/day, Mg = 420 mg/day, Zn = 11 mg/day and Se = 0.06 mg/day (Bilandžic et al., 2015; Dietary Reference Intakes, 2020).

Results

After analyses of the eight food substances, varying levels of Ca, Fe, K, Mg, and Zn were observed. As shown in Figure 1, the concentration of potassium in each of the selected samples was the highest and levels of selenium in each sample were below detectable limits. The levels of the macro elements Ca, K and Mg were above 5000 mg/kg dw and the levels of the micro-elements Fe and Zn were below 150 mg/kg dw in all samples.

The contribution of each element to the RDA was determined for a 4 g dry weight of food sample (Figure 2). The RDA contributions were based on the values for men at 40 years and above (Bilandžic et al., 2015; Dietary Reference Intakes, 2020). Magnesium had the highest contribution to RDA in all food substances analyzed. Except for watermelon seeds and tigernut, zinc had the lowest contribution to RDA in all samples investigated.

Levels of micro- and macro-elements in carrots was in the decreasing order: K (37,354.33 ± 121.25 mg/kg dw) > Mg (9037.33 ± 916.00 mg/kg dw) > Ca (8443.33 ± 8.00 mg/kg dw) > Fe (81.33 ± 1.50 mg/kg dw) > Zn (27.33 ± 0.50 mg/kg dw) which are comparable with reported values (Warman and Havard, 1997). Consuming 4 g of dry carrots can provide 8.61% of the RDA for Mg, 4.07% for Fe, 3.38% for Ca, 3.18% for K and 0.99% for Zn.

Cucumber is rich in K (71,112.67 ± 358.50 mg/kg dw), Ca (10,866.67 ± 25.75 mg/kg) and Mg (12,033.33 ± 2366.75 mg/kg dw). Concentrations of Fe (142.33 ± 3.25 mg/kg dw) and Zn (46.33 ± 0.50 mg/kg dw) were relatively low since they are micro-elements and these figures fall within reported ranges in literature (Abbey et al., 2017; Rahman et al., 2015). Consuming 4 g of dry cucumber can supply 11.46% of the RDA of Mg, 7.12% of the RDA of Fe, 6.05% of the RDA of K, 4.35% of the RDA of Ca and 1.69% of the RDA of Zn.

The results revealed that watermelon rind contained higher levels of potassium (46,608.67 ± 76.16 mg/kg), zinc (44.33 ± 1.53 mg/kg) and calcium (14,560.67 ± 10.02 mg/kg) than the pulp (29,256.67 ± 66.52 mg/kg of K, 9.67 ± 0.58 mg/kg of Zn and 5698.00 ± 6.00 mg/kg of Ca). The seeds of watermelon contained comparable levels of Ca and Mg with the pulp and higher levels of Fe and Zn than the pulp. The levels of Zn and Mg in the seeds were comparable with that of the find. The results are consistent with data reported in literature (Cemaluk and Egbuonu, 2015; Morais et al., 2005).

Aside phytochemicals, garlic is also rich in K (30,718.00 ± 18.75 mg/kg dw), Ca (6323.33 ± 21.25 mg/kg dw), Mg (2587.00 mg/kg dw), Fe (57.33 ± 1.25 mg/kg) and Zn (49.33 ± 0.50 mg/kg dw). These levels are higher than values reported in literature (Otunola et al., 2010). Consumption of 4 g of dry garlic will provide 1.79%–2.87% of the RDA of the elements under investigation.

Ginger contains K (24,814.67 ± 63.75 mg/kg dw), Ca (5980.33 ± 0.68 mg/kg dw), Mg (9163.00 ± 299.75 mg/kg dw), Fe (103.00 ± 1.00 mg/kg dw) and Zn (44.33 ± 1.50 mg/kg dw). In terms of contribution to RDA, Mg has the highest contribution (8.73%) followed by Fe (5.15%). Zn has the least contribution of 1.61% to RDA. The levels of the metals reported in this work are higher than values reported in literature (Otunola et al., 2010).

Nutmeg, a popularly consumed spice, is rich in K (12,392.00 ± 51.75 mg/kg dw), Mg (10,698.33 ± 1746.00 mg/kg dw), Ca (8035.00 ± 9.25 mg/kg dw), Fe (101.33 ± 4.25 mg/kg dw) and Zn (19.67 ± 0.50 mg/kg dw). The results are generally higher than reported data (Borquaye et al., 2017). Consumption of 4 g of dry nutmeg will provide 0.72%–10.19% of the RDA of the elements under

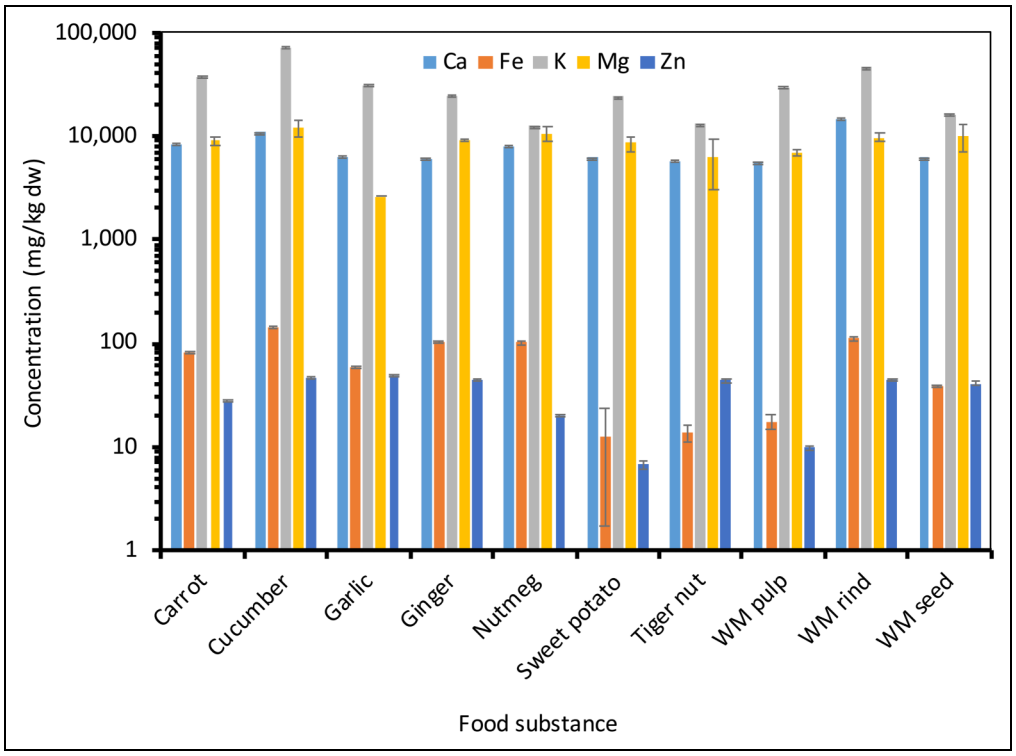

Figure 1. Micro- and macro-elemental content in food substances used to treat ED. WM is watermelon. Data represent the mean of 3 separate determinations and error bars represent standard deviation. Levels of selenium were below detectable limit in all samples. ED: erectile dysfunction.

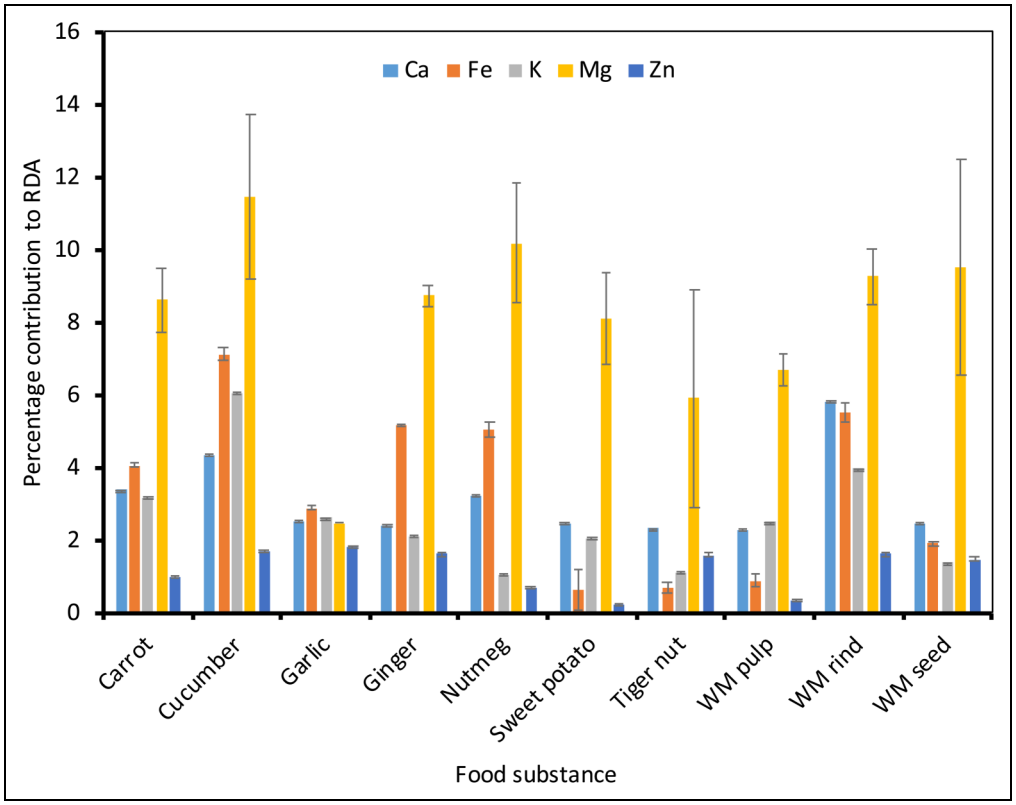

Figure 2. Contribution of elements to RDA from the consumption of 4 g of dry food substance.

investigation. Mg has the highest contribution to RDA and Zn has the lowest contribution.

Sweet potato is rich in K (24,085.33 ± 105.25 mg/kg dw), Mg (8507.67 ± 1322.25 mg/kg dw), Ca (6196.67 ± 3.25 mg/kg dw), Fe (12.67 ± 11.00 mg/kg dw) and Zn (6.67 ± 0.50 mg/kg dw). These results are higher than reported figures (Mohanraj and Sivasankar, 2014). From the results of this study, a 4 g dry sample of sweet potato can provide 8.10% of Mg RDA, 2.48% of Ca RDA, 2.05% of K RDA, 0.63% of Fe RDA and 0.24% of Zn RDA.

This study revealed that tiger nut, usually consumed as a snack or dessert, contains K (12,952.67 ± 59.70 mg/kg dw), Mg (6189.00 ± 3128.00 mg/kg dw), Ca (5771.00 ± 4.00 mg/kg dw), Zn (43.33 ± 1.50 mg/kg dw) and Fe (13.67 ± 2.50 mg/kg dw). These results fall within ranges reported in literature (Suleiman et al., 2018). Consumption of 4 g of dry tiger nuts can supply 5.89% of the RDA of Mg, 2.31% of the RDA of Ca, 1.58% of the RDA of Zn, 1.10% of the RDA of K, and 0.68% of the RDA of Fe.

Discussion

This study investigated the elemental composition of selected food items used to manage and treat ED. The study revealed that the food items are rich in minerals that support biochemical processes that enhance penile health.

Carrot has been used in the management of age-related and atherogenic ED (Helmy and Senbel, 2012). The use of carrot in the management of ED may be partly attributable to its high content of vitamin E and phenols (Nicolle et al., 2004) and partly to the supply of an appreciable amount of Mg, Fe, Ca and K which might work in concert with the phenols and vitamin E to elicit aphrodisiac activity.

Watermelon and cucumber are rich in citrulline, a non-essential amino acid that plays a vital role in the pathophysiology of erection (Shiota et al., 2013). Watermelon seeds, pulp and rind were analyzed separately since studies have shown different citrulline (Rimando and Perkins-Veazie, 2005) and elemental composition (Morais et al., 2005) for the various parts of the watermelon fruit. Watermelon rind and cucumber fruit can promote erection by increasing penile blood flow due to high potassium concentration, increasing nitric oxide synthesis due to high calcium levels and improving testosterone production due to high zinc levels. Munglue et al. (2014), showed that extracts of the watermelon seeds promote sexual activity, spermatogenesis and erection in male rats. The aphrodisiac potential of the seeds may be attributed to the activity of phytochemical constituents with the elements serving as adjuncts.

Garlic and nutmeg are popularly consumed spices that also act as aphrodisiacs. Garlic increases the levels and activity of nitric oxide synthase, an enzyme that catalyses the synthesis of nitric oxide in the vasodilation signal transduction pathway (Das et al., 1995). Garlic also contains allicin, an organo-sulphur compound that helps in the management of hypertension and high cholesterol levels (Ali et al., 2000). These conditions increase the risk of ED and can promote the disease progression in those already with ED. From the finding of this work, it can be deduced that the aphrodisiac properties are derived not only from the phytochemicals but also from the mineral composition.

Ginger rhizome has been used in traditional medicine for the treatment of infertility, ED, and impotence in men for ages (Nimrouzi et al., 2020). Ginger also helps in cholesterol and blood pressure control which are risk factors for ED (Chinedu and Jivini, 2019). Studies in Wistar rats revealed that ginger extracts can improve sexual function (Khaki et al., 2012). Ethanolic extracts of nutmeg produced enhanced erection in male rats and this was attributed to the stimulatory effects of phenols, amino acids and other phytochemicals on the nervous system (Ahmad et al., 2005). The results from this study reveal that ginger and nutmeg also contain micro- and macro-elements that support penile health.

Mineral levels in sweet potato are moderate compared to the other food substances investigated in this work. However, sweet potato is practically consumed in larger quantities. A tuber with an average dry mass of 85 g (mean weight 100 g, moisture content 15%) of sweet potato will contain 9302.4 mg of potassium, which is proportional to 43% of the RDA of potassium. Thus, sweet potato can supply adequate levels of minerals and therefore increase penile blood flow.

Tiger nuts are believed to possess aphrodisiac properties and are widely used folklorically in the management of ED. A study by Allouh et. al. (2015) revealed that the high concentration of Zn and Se in tiger nut facilitated an increase in the copulatory behaviour of rats by increasing testosterone production. Phytochemicals like oleic acid (Aremu et al., 2016) and vitamin E (Belewu and Abodunrin, 2006) in tiger nuts also contribute to its ability to enhance erection. The use of tiger nut in the management of ED could be due to the complementary effect of the phytochemicals and the minerals present.

Conclusion

This work has revealed that food substances used in the management and treatment of ED contain variable amounts of K, Ca, Mg, Fe and Zn. Se levels were below detection in all food samples analyzed. These elements play key roles in the pathophysiology of erection and their deficiencies have been implicated in ED. Though levels of potassium were highest in the food, magnesium contributed greatest to RDA. The contributions of the elements to RDA indicate that consuming 4 g of the dry food substances does not provide an adequate amount of micro- and macro-elements implicated in ED. However, people who take these food substances for the treatment of ED consume them frequently in large quantities and in combinations over a long period. This will supply an

appreciable quantity of the mineral requirements to supplement the phytochemicals provided by these foods to enhance penile erection.

The total amount of micro- and macro-elements implicated in ED were in the order cucumber > watermelon rind > carrot > watermelon pulp > ginger > garlic > sweet potato > watermelon seed > nutmeg > tiger nut. In terms of contribution to RDA, the order is cucumber > watermelon rind > nutmeg > carrot > ginger > watermelon seed > sweet potato > watermelon pulp > garlic > tiger nut. The results of this study support the therapeutic usage of these food substances in alternate and complementary medicine for the treatment and management of ED since they contain appreciable amounts of Mg, K, Zn, Ca and Fe. Cucumber and watermelon, known to be rich in citrulline, also provide the highest concentration of micro- and macro-elements needed to enhance penile erection.

Consent for publication

All authors consent for the publication of this article.

Author contributions statement

ML, SF-M, and DB conceptualized and planned the work. ML, SF-M and SOA collected and prepared the samples and evaluated the analytical results. AAR-M and SOA performed the XRF measurements under the supervision of DB and they all assisted in the evaluation of the results. ML drafted while SFM technically edited the script. All authors read and contributed to the final manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical statement

All authors have been personally and actively involved in substantive work leading to the manuscript, and will hold themselves jointly and individually responsible for its content.

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