Research Article

Estimating the potential of spices for mineral provision in a refugee context in East Africa

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Abstract
Micronutrient deficiency remains an enormous problem in refugee settings. Transforming refugees' food systems through the scaling up of kitchen gardening and fortifying relief food crops with minor food components including nutrient-dense spices can help improve the quality of staple foods. Globally, spices are indispensable in the daily diet and play an important role in the socio-cultural setting of different communities. Forty turmeric and curry powder samples were collected from different market establishments and geographic locations in East Africa. The samples were analyzed for selected elements using Portable X-Ray Fluorescence (PXRF). The contents of potassium (K), calcium (Ca), zinc (Zn) and strontium (Sr) in turmeric powder were statistically different among geographic origins (Ethiopia, Kenya and Uganda). We also aimed to determine if a small portion of spices (turmeric (5 g) and curry (4 g)) would contribute to an adequate intake (AI) or recommended dietary allowance (RDA) for selected minerals, for refugee men and women aged between 19 and 50 years as defined by the Food and Nutrition Board of the Institute of Medicine (IOM). For the reference groups, the contributions of turmeric and curry powder to AI/RDA for K, Ca and Zn varied between 0.48 to 4.13%. On the other hand, turmeric was identified to contribute > 20% AI/RDA for refugee men and women aged between 19 and 50 years for two micro minerals: manganese (Mn) and iron (Fe). Considering turmeric and curry powder of East African origins are good sources of minerals and present acceptable toxic metal(loid)s loads coupled with low cost, these spices particularly turmeric should be more widely popularized and recommended for food-to-spice fortification among the refugee population located in East Africa.

Highlights

- Information concerning the mineral contents of spices is lacking.
- Spices are a good source of several minerals and contribute to dietary intakes of nutritionally important minerals.
- Nutrition intervention, including food-to-spice fortification for improving mineral intakes by refugee community, is required.

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1 Introduction

In East Africa, the refugee diet is characterized by two prevailing aspects: (i) Prevalence of high-calorie cereal-based foods and (ii) Insufficient intake of micronutrients [1, 2]. Hence, micronutrient deficiency remains an enormous problem in refugee settings [3, 4]. Among the numerous approaches towards reducing micronutrient deficiency in a refugee context, transforming refugees' food systems through the scaling up of kitchen gardening for the production of socially acceptable and nutrient-dense food crops is perceived as a sustainable solution [5, 6]. In addition, fortifying relief food crops with minor food components including nutrient-dense spices can help improve the quality of staple foods in a refugee setting. In fact, spices are indispensable in the daily diet and play an important role in the socio-cultural setting of different communities throughout the world [7–9]. Globally, the spices and seasonings market value were 17.12 billion USD in 2020 [10]. Turmeric and curry powder are among the top 10 most commonly consumed spices world-wide [11]. For millennia, turmeric has been consumed as a culinary and coloring agent as well as a traditional healing agent for a wide variety of health disorders ranging from gastric upset to cancers [12, 13]. It is now well established that mineral deficiency or excessive intakes of potentially toxic metal(loid)s could be deleterious to human health [14, 15]. In fact, refugees traditionally use a wide range of local food resources and spices in their daily diets [6]. However, the potential contribution of locally available spices for food-to-spice fortification towards better nutrition have rarely been considered. Therefore, determination of elements in foods and related products, including spices, is critical for identifying the nutritional importance and potential health risks associated with fortification [8, 9, 15].

Until recently, spices have received little attention from a nutritional point of view because it was thought that their intake is limited to very small quantities [16, 17]. Nonetheless, spices, including turmeric, are storehouses of minerals [8, 9, 18]. For example, it has been reported that, a daily intake of turmeric in the amount of 5 g could contribute about 28% RDA for iron (Fe) for men aged between 19 and 50 years [9]. However, spices may also contain excessive levels of toxic and potentially toxic metal(loid)s [14, 19]. Heavy metal contents of individual spices vary according to growing condition, agronomic practices and processing [20]. Moreover, economically motivated adulteration is becoming a cause of heavy metal contamination [21]. For example, in South Asia and North America, some studies have implicated the market driven additions of lead chromate ($PbCrO_4$) and lead oxide (PbO) to enhance weight, color and to hide spots and marks originating from pest attacks on raw turmeric occurring over the value chain [14, 22]. This has been linked to high blood lead (Pb) levels of various communities in India and Bangladesh [14, 23]. The problem could be further exacerbated through the release of hexavalent chromium (Cr) from the incorporation of $PbCrO_4$ to turmeric [13, 14, 24].

Despite widespread consumption of spices (turmeric in particular), spices have scarcely been studied in terms of their mineral and toxic metal(loid) contents across East African territories [9]. Establishing a sub-regional context for selected elements in popular spices including turmeric powder is required for nutritional and food safety advice in refugee settings and beyond, as well as for regulatory standard setting. Inductively coupled plasma and atomic absorption/emission modalities (ICP-MS, ICP-OES, ICP-AES, AAS, AES and GF-AAS) are the principal analytical approaches employed for assessment of elements in spices and condiments [8, 9, 25]. Although these modalities have been reported as the best methods for reliable multi-element determination with excellent sensitivity, XRF-based techniques may also be effectively employed for multi-element screening, especially owing to their low-cost, fast, dry, and direct method of measurement [26, 27]. Thus, in the current study, we sought to evaluate the contents of elements in both turmeric and curry powder available in East African markets using the PXRF method. The contribution of turmeric and curry powder consumption via food-to-spice fortification/enrichment to adequate intake (AI) or recommended dietary allowance (RDA) for selected minerals was estimated. In the section which follows, we describe the materials and methods used in this study of turmeric and curry powder. Thereafter, Sect. 3 presents the results in terms of both elemental contents and contributions to AIs/RDAs. In Sect. 4, we provide a discussion of results and their implications. Finally, Sect. 5 provides a brief conclusion, with a view toward the future.

2 Materials and methods

2.1 Sample collection and preparation

Forty turmeric and curry powder samples (50–500 g) were procured from East African countries (Ethiopia, Kenya and Uganda) during a BMZ funded project-inception workshop and during refugee camp orientation visits between the months of September 2019 and November 2019. The powder samples were collected and stored in polyethylene bags prior to shipment to New Brunswick, Canada.

2.2 PXRF analyses

The PXRF analyses were performed using an HD Mobile system (X-ray Optical Systems; East Greenbush, NY, USA). This system has been described in detail elsewhere [26]. Briefly, the operating characteristics of the system include mono-energetic excitation capabilities, a molybdenum X-ray tube anode, an X-ray tube current of 200 µA, and a tube voltage of up to 50 kV. The radiation detector is a silicon drift detector [28]. The system was operated in the tabletop mode, as illustrated by Fig. 1. For each measurement, a powdered spice sample was analyzed by placing it first in a 32 mm-diameter X-ray fluorescence sample cell (SCP Science; Baie-d'Urfé, QC, Canada), sealed with a 4 µm-thick prolene film.

The sample was then positioned on the platform directly above the X-ray beam window. Each sample had an approximate mass of 0.4 g. X-ray beam profiles and measurement time (30 s real time) protocols have been described elsewhere [15]. Each of the 40 samples (Fig. 2) was measured three times, with no sample repositioning between measurements. A total of 120 (40*3) measurements were therefore made using this procedure. Concentrations for various elements were output directly from the HD Mobile system, based on manufacturer-provided calibrations. We used the "low energy" beam results for potassium (K) and calcium (Ca), and the "high energy" beam results for manganese (Mn), iron (Fe), zinc (Zn), arsenic (As), strontium (Sr), rubidium (Rb) and lead (Pb). Limits of detection ranged from 3.9 mg kg^{-1} for Rb to 1040 mg kg^{-1} for K, while limits of quantitation ranged from 13 mg kg^{-1} for Rb to 3480 mg kg^{-1} for K.

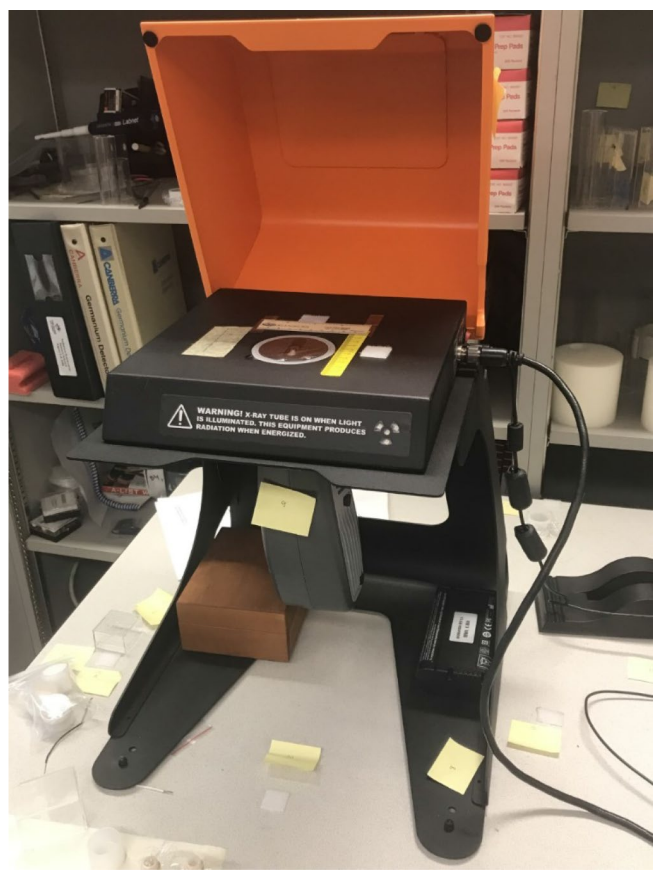

Fig. 1 The portable XRF system when operated in a tabletop mode. Here, the radiation protection lid is shown open and ready for sample placement

Fig. 2 The complete collection of 40 powder spice samples in sample cups

2.3 Estimation of turmeric and curry powder consumption to AI/RDA for selected minerals

Average per capita daily consumption of spice varies considerably among locations, even within the same country [29–31]. Since no daily intake recommendation has yet been made for spices (particularly turmeric and curry powder), in the present study, the following assumption has been made: 5 g (turmeric) and 4 g (curry powder) are assumed as standard portions for refugee men/women aged between 19 and 50 years [29, 32]. Daily intake levels of selected macro and micro-minerals associated with turmeric and curry powder were estimated from the PXRF measured concentrations and compared with AI/RDA values for the reference groups (refugee men and women aged between 19 and 50 years) as commended by the IOM [33–35].

2.4 Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 23. The mean concentrations of analyzed elements in spices were statistically evaluated by analysis of variance (ANOVA) followed by Duncan's post hoc test for different geographic origins. Student's t test was applied to check the significant difference in element concentrations between branded and non-branded groups. Statistical significance was established at $p < 0.05$.

3 Results

3.1 Contents of elements in turmeric and curry powder

The PXRF-based elemental concentrations in turmeric and curry powder samples collected from markets in East Africa are presented in Table S1 where the mean concentration of each element (n = 3) is given together with the standard deviation value. The ranges of concentrations for K, Ca, Mn, Fe, Zn, Rb and Sr in turmeric powder samples were: 8277–41,949, 477–2633, 25.9–246, 257–3074, 4.9–40.9, 4.3–69.1 and 4.8–22.6 mg kg^{-1}, respectively. ANOVA followed by Duncan's post hoc test revealed significant differences in mean contents of K, Ca, Zn and Sr among geographic origins (Ethiopia, Kenya and Uganda) for turmeric (Table 1).

Similarly, ranges of concentrations for K, Ca, Mn, Fe, Zn, Rb and Sr in curry powder samples were: 6689–20,450, 891–5849, 41.7–188, 158–2359, 16.1–72.1, 8.6–46.2 and 14.6–39.4 mg kg^{-1}, respectively (Table S1). Geographically, statistically higher Ca, and Fe contents in curry powder were obtained from markets in Ethiopia. The Ca contents varied significantly with a range (mean value) from 1.47 g kg^{-1} in curry powder from Uganda to almost 3.6 times higher in curry powder from Ethiopia with a mean value of 5.24 g kg^{-1}. For Mn, a significant variation amongst geographic origins was also observed, in which Ethiopian and Ugandan curry powder exhibited

Table 1 Statistics of elemental concentrations in turmeric and curry powder samples (mean ± SD) by their geographic origins. K, Ca and Fe are reported in g kg^{-1} and values are given in mg kg^{-1} for Mn, Zn, Rb and Sr

Spices		K	Ca	Mn	Fe	Zn	Rb	Sr
Turmeric	Ethiopia	$12.8^{a}\pm6.4$	$0.95^{a}\pm0.43$	111 ± 42.9	1.17 ± 0.45	$21.1^{a}\pm5.41$	9.75 ± 5.53	$8.67^{a}\pm3.51$
	Kenya	$28.6^{b}\pm11.5$	$2.01^{b}\pm0.62$	122 ± 90.3	1.04 ± 1.03	$17\pm9^{a}.94$	25.4 ± 27.2	$13.5^{b}\pm3.54$
	Uganda	$20.2^{ab}\pm3.74$	$1.79^{b}\pm0.53$	176 ± 47.3	0.89 ± 0.12	$36.7^{b}\pm4.83$	16.2 ± 0.75	$21.3^{c}\pm1.11$
Curry	Ethiopia	13.4 ± 1.35	$5.24^{a}\pm0.89$	$135^{a}\pm36.6$	$1.62^{a}\pm0.81$	$22^{a}\pm4.4$	14.9 ± 2.04	$29^{a}\pm3.86$
	Kenya	13.9 ± 4.77	$3.18^{b}\pm1.51$	$72.7^{b}\pm15.3$	$0.36^{b}\pm0.17$	$31.1^{a}\pm10.6$	21.9 ± 16.7	$28.4^{a}\pm9.08$
	Uganda	14.6 ± 1.05	$1.47^{c}\pm0.14$	$139^{a}\pm13.7$	$0.28^{b}\pm0.01$	$65.3^{b}\pm4.55$	9.58 ± 0.29	$15.3^{b}\pm0.54$

Different letters along a column within a spice group represent significant differences at $p < 0.05$

Table 2 Differences in mean concentrations of elements between branded and non-branded turmeric samples from East African markets. K, Ca and Fe are reported in g kg^{-1} and values are given in mg kg^{-1} for Mn, Zn, Rb and Sr

Element	Non-branded	Branded
K	$13.9^{a}\pm6.1$	$24.1^{b}\pm11.4$
Ca	1.16 ± 0.66	1.72 ± 0.65
Mn	125 ± 53.6	130 ± 74.8
Fe	$0.94^{a}\pm0.22$	$1.21^{b}\pm0.85$
Zn	27.6 ± 8.57	18.4 ± 9.05
Rb	$10.6^{a}\pm4.97$	$20.9^{b}\pm21.5$
Sr	12.7 ± 7.62	12.6 ± 3.63

Values with different letters within a row differ significantly at $p < 0.05$

concentrations far above Kenyan curry with mean values of 135 and 139 mg kg^{-1}, respectively. For curry samples from Uganda, the content of Zn was the highest among the three countries.

When data from all geographic origins were pooled together (i.e., Ethiopia, Kenya and Uganda), Student's t test revealed that a significant difference was obtained between non-branded and branded turmeric samples for mean contents of K, Fe and Rb while the concentrations of Ca, Mn, Zn and Sr showed no significant differences between branded and non-branded forms (Table 2).

3.2 Contribution to AIs/RDAs

To evaluate the nutritional characteristics of turmeric and curry powder, the estimated daily intakes of selected minerals were compared against AI/RDA values. As presented in Table 3, turmeric could potentially contribute to <5% AI for K and Ca when a 5 g portion is consumed daily. Curry was also identified to contribute <3% AI for K and Ca through the daily consumption of 4 g of powder. The potential contributions of turmeric and curry powder ranged from 20 to 48.9% AI for Mn. The RDA for Fe is estimated to be 8 mg/person/day for men aged between 19 and 50 years, while the RDA for women of the same age group is 18 mg/person/day [34]. Five grams of turmeric could ensure > 20% RDA for Fe for the reference groups. On the other hand, for Zn, the two spices could contribute little to RDA for the reference groups.

Table 3 Percentage contribution to adequate intake (AI) or recommended dietary allowance (RDA) through the daily consumption of 5 g turmeric and 4 g curry powder by men/women aged between 19 and 50 years

Spices	Geographic origins	Daily intake, mg/person/day (% contribution to AI/RDA)				
		K	Ca	Mn	Fe	Zn
Turmeric	Ethiopia	64 (1.36)	4.75 (0.48)	0.56(24.3)/(31.1)	5.85(73.1)/(32.5)	0.11(1)/(1.38)
	Kenya	143 (3.04)	10.1 (1.01)	0.61(26.5)/(33.9)	5.20(65)/(28.9)	0.09(0.82)/(1.13)
	Uganda	101 (2.15)	8.95 (0.90)	0.88(38.3)/(48.9)	4.45(55.6)/(24.7)	0.18(1.64)/(2.25)
Curry	Ethiopia	67 (1.43)	26.2 (2.62)	0.68(29.6)/(37.8)	8.10(101)/(45)	0.11(1)/(1.38)
	Kenya	69.5 (1.48)	15.9 (1.59)	0.36(15.7)/(20)	1.80(22.5)/(10)	0.16(1.45)/(2)
	Uganda	73 (1.55)	7.35 (0.74)	0.70(30.4)/(38.9)	1.40(17.5)/(7.78)	0.33(3)/(4.13)
AI/RDA for men/women aged between 19 and 50 years		4700/4700	1000/1000	2.3/1.8	8/18	11/8

AI Adequate intake) or *RDA* Recommended dietary allowance established by the Food and Nutrition Board of the Institute of Medicine (IOM) [31–33]

4 Discussion

Until recently, since plain spice consumption is rare, spices were not considered important in dietary assessment surveys. This paper presents preliminary PXRF information about selected elements in turmeric and curry powder marketed across East Africa. A more extensive future investigation of this kind could include additional spices. Regardless of geographic origin, K and Ca were the most abundant macro minerals in turmeric powder. This result is consistent with the findings of Datta et al. [36] who reported notably higher levels of K and Ca in branded turmeric powder marketed across India. Similar observations indicating higher contents of K (28.8 g kg^{-1}) and Ca (2.3 g kg^{-1}) were reported by Oh and Kim [37] for turmeric from Korea. Curry powder is also characterized by high median levels of K (13.4–14.6 g kg^{-1}) and Ca (1.47–5.24 g kg^{-1}). These values are in accordance with the results obtained by Siong et al. [38] and Britto et al. [39]. It should be emphasized that despite low K and Ca intake contributions from low turmeric consumption, both turmeric and curry powder are storehouses of K and Ca. It is also noted that East African turmeric and curry powder are rich in Fe and Mn. Statistically, the highest mean Fe content was obtained for curry powder samples from Ethiopia. Higher contents of Mn in turmeric and curry powder were reported in the literature [8, 9, 18]. Similarly, curry powder samples collected from different locations and market outlets in Ethiopia exhibited high mean Fe content. For turmeric powder, the levels reported in the literature coincide with the values obtained in the present study (546 mg kg^{-1}, [40]; 446 mg kg^{-1}, [9]). In fact, processing may significantly increase the level of Fe in both turmeric and curry powder. The Zn level in curry powder from Uganda was consistent with the value reported by Onianwa et al. [41]. Similarly, we reported comparable levels of Zn from Ethiopia and Kenya with the levels obtained by Nnorom et al. [42]. The significant variation in elemental concentrations of curry powder among geographic origins could be attributed to varying blend ratios according to regional preferences and tradition [31]. Other possible explanations for variations include differences in processing, maturity stages of the spice plants, and management practices of individual spice plants [8]. With the exceptions of K, Fe and Rb, no significant differences were obtained for elemental contents between non-branded and branded turmeric samples. The same observation was made by Akhtar et al. [19] for the concentration of toxic elements in non-branded and branded turmeric samples from Pakistan.

Turmeric and curry powder samples had As and Pb contents less than 1 mg kg^{-1} (Data not shown). The reported Pb contents were in good agreement with the literature values obtained in raw and powder turmeric samples from various geographic territories [8, 43–46]. Conversely, several studies (e.g. [9, 47]) have reported far higher levels of Pb compared with the maximum tolerable concentration (10 mg kg^{-1}) stipulated by WHO [48]. Recently, Forsyth et al. [13] reported higher content of Pb in selected turmeric samples from Bangladesh. According to these authors, adulteration by $PbCrO_4$ could be a likely route of contamination as it is supported by high Cr levels. Our study suggested that adulteration of turmeric with pigments in samples from the East Africa sub-region is non-existent. This may incentivize the safe use of turmeric for food-to-spice fortification in refugee settings.

Depending on life stages, the AI values for K and Ca vary between 1000 and 4700 mg/day [32, 34] and as such turmeric and curry powder might contribute little to dietary intake at the proposed intake levels. However, it is noteworthy that these estimates are based on low enrichment levels. A comparison of mineral composition of turmeric and curry powder with conventional cereals such as maize indicates that the supply of Ca, in particular, from the consumption of these spices would be superior [49, 50]. For example, a 100 g of maize grain would have contributed 0.22% AI for Ca [51]. So, in a refugee setting where maize grain is a staple crop; the contributions to AI for K and Ca from the consumption of these spices are considerable. As Mn is ubiquitous in food commodities, Mn deficiency is especially unlikely. For example, a teaspoon of turmeric (5 g) would contribute to 31.1–48.9% AI for women aged between 19 and 50 years. The World Health Organization (WHO) lists Fe deficiency as the 6th leading causes of illness and disease in low income countries [52]. According to the present study, a teaspoon of turmeric contains approximately 5.2 mg of Fe, which would contribute to > 50% RDA for refugee men aged between 19 and 50 years. From the sub-Saharan Africa's perspective, turmeric and curry powder could be a promising source of Fe. Overall, owing to their mineral-dense nature and affordability, turmeric and curry powder could be highlighted as one of the plausible strategies in improving micro-mineral status of nutritionally vulnerable groups [44]. Evidently, none of these spices are taken in isolation, but are taken as ingredients and will enhance the nutritional value of other food items. A popular growth area for turmeric is the fortification of other food items [53]. Recently, Idowu-Adebayo et al. [54] demonstrated that the fortification of a popular Nigerian street drink (zobo) with turmeric could contribute significantly towards the required intakes of Fe and Zn. In fact, the Nigerian Government is promoting the turmeric crop. This would also be applicable in the rest of sub-Saharan Africa where turmeric is widely available.

5 Conclusion

This study has shown that the spices are excellent sources of minerals including K and Ca compared with aid cereals in emergency settings. The data may help contribute to the development of an East African spices and condiments composition data base. The potential contribution of spices towards AI/RDA for the elements analyzed may have been well above the current estimates had all the staple spices, which are perennially consumed in East Africa, been considered. Therefore, in the future, all staple spices and condiments should be fully investigated in terms of nutrient composition including macro- and micro-minerals. However, the results of the present study as provided are informative for estimates of elemental intake from these spices of interest. Overall, the additional knowledge presented here about the dietary intakes of minerals from the consumption of two spices via fortification/enrichment, turmeric and curry powder, will help better inform potential nutritional advice in refugee settings and beyond. For example, one option of improving nutritional awareness of spices is in the context of the Sphere Handbook [55], as two complementary food response options are included: (1) Provision of cash-based assistance to purchase locally available fortified and nutrient rich foods and; (2) Distributing nutrient rich household foods or fortified foods. This study shows that both the spices turmeric and curry powder would be highly relevant in the context of these food response options.

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Data Availability All relevant data and material are visible in the manuscript and the supporting information.

Declarations

Conflict of Interests The authors declare no competing interests.

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